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THE GRAPE PHYLLOXERA.

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THIS is an insect which is attracting much attention just now, and which has held a very prominent place in economic entomological literature during the past five years. It has occurred to me that it would not be uninteresting to the many readers of The Popular Science Monthly to have the facts now known about it laid before them in a popular form, and with as little of the nomenclature of science as is consistent with precision. I therefore transmit the following advance matter from the forthcoming sixth "Entomological Report of Missouri," very slightly modified to adapt it to the pages of the Monthly.

To many the term "Phylloxera" is void of meaning, so that it may not be amiss to say, at the outset, that it is a term derived from the Greek (*φύλλον* and *ξηρός*), meaning *withered-leaf*, and founded many years ago,[1] by Boyer de Fonscolombe, to designate a peculiar genus of plant-lice. It was originally erected for a species (*Phylloxera quercus*) quite common in Europe on the under side of oak-leaves, which, in consequence of its punctures, wear a withered appearance. The genus now comprises several species, none of them affecting man's interests except the species under consideration (*vastatrix* Planchon). This, on account of its injurious work, has acquired such prominence that the generic term has come to be used in a broader sense, and to indicate at once the insect and the disease it produces; just as in botany the term *oidium*, though originally referring only to a genus of cryptogamic plants, is now popularly employed to designate the mildew on grape-vines, caused by *Oidium Tuckeri*.

BIBLIOGRAPHICAL.

The first published reference to this insect was made in the year 1856,[2] by Dr. Asa Fitch, the State Entomologist of New York, who

[1] "Annales de la Société Entomologique de France," tome iii., p. 222.

[2] "New York Entomological Reports," vol. i., p. 158.

subsequently described the gall-inhabiting type of it, which I have termed *gallæcola*, in a rather insufficient manner,[1] by the name of *Pemphigus vitifoliæ*. Dr. Fitch knew very little of the insect, as we understand it to-day. It was subsequently treated of by several American authors, and in January, 1867, Dr. Henry Shimer, of Mount Carrol, Ill., proposed for it a new family (*Daktylosphæridæ*),[2] which has not been accepted by homopterists, for the reason that it was founded on characters of no family value.

All these authors referred to the leaf-louse described by Dr. Fitch, and never dreamed that the insect existed in another type on the roots. During the few years following our civil war a serious disease of the Grape-vine began to attract attention in France, and soon caused so much alarm that the Minister of Agriculture and Commerce in that country offered a prize of 20,000 francs for an effectual and practicable remedy; and a special committee was appointed to draw up a programme of conditions, and award the prize if it saw fit so to do.

The disease is known as *pourridie*, or rotting, the roots becoming swollen and bloated, and finally wasting away. There were no end of surmises and theories as to its cause, until Prof. J. E. Planchon, of Montpellier, in July, 1868, announced[3] that it was due to the puncture of a minute insect belonging to the plant-louse family (*Aphididæ*), and bearing a close resemblance to our gall-louse. The insect was subsequently described, by the same author, from the apterous form, under the name of *Rhizaphis vastatrix*, and not till September of the same year[4] when the winged insect was discovered, did he give it the name by which it is now so well known. In January, 1869, Prof. J. O. Westwood, of Oxford, England, announced[5] the receipt of both the gall and root-inhabiting types, from different parts of England and Ireland, and his inability to distinguish between the two. In the same article he announced having received the gall-making type from Hammersmith in 1863, and having described it by the name of *Peritymbia vitisana*, in a notice communicated to the Ashmolean Society of Oxford, in the spring of 1868, which communication was, I believe, never published. In the spring of 1869,[6] M. J. Lichtenstein, of Montpellier, first hazarded the opinion that the Phylloxera, which was attracting so much attention in Europe, was identical with the American insect described by Dr. Fitch. This opinion gave an additional interest to our insect, and I succeeded in 1870, while the Franco-Prussian war was at its highest, and just before the investment of Paris, in establishing the identity of their gall-insect with ours, through correspondence with, and specimens sent to, Dr. V. Signoret, of that city. During

[1] Report, vol. iii., § 117.

[2] Proceedings Academy of Natural Sciences, Philadelphia, January, 1867.

[3] *Messager du Midi*, July 22, 1868.

[4] "Comptes rendus de l'Académie des Sciences de Paris," September 14, 1868.

[5] *Gardeners' Chronicle*, January 30, 1869. [6] "Insectologie Agricole," 1869, p. 189.

the same year I also established the identity of the gall and root-inhabiting types, by showing that in the fall of the year the last brood of gall-lice betake themselves to the roots and hibernate thereon. In 1871 I visited France and studied their insect in the field; and in the fall of that year, after making more extended observations here, I was able to give absolute proof of the identity of the two insects, and to make other discoveries, which not only interested our friends abroad, but were of vital importance to our own grape-growers, especially in the Mississippi Valley. I have given every reason to believe that the failure of the European vine (*Vitis vinifera*) when planted here, the partial failure of many hybrids with the European *vinifera*, and the deterioration and death of many of the more tender-rooted native varieties, are mainly owing to the injurious work of this insidious little root-louse. It had been at its destructive work for years, producing injury the true cause of which was never suspected until the publication of the article in the "Fourth Entomological Report of Missouri." I also showed that some of our native varieties enjoyed relative immunity from the insects' attacks, and urged their use for stocks, as a means of reëstablishing the blighted vineyards of Southern France.

The disease continued to spread in Europe, and became so calamitous in the last-named country that the French Academy of Science appointed a standing Phylloxera Committee. It is also attracting some attention in Portugal, Austria, and Germany, and even in England, where it affects hot-house grapes.

The literature of the subject grew to such vast proportions that, after publishing a biographical review, containing notices and summaries of 484 articles or treatises published during the four years of 1868–'71, MM. Planchon and Lichtenstein gave up the continuance of the work as impracticable.

At the suggestion and with the coöperation of the Société Centrale d'Agriculture de l'Hérault, the French Minister of Agriculture last autumn commissioned Prof. Planchon to visit this country and learn all he could about the insect and its effects on our different vines. Prof. Planchon arrived here the latter part of August and remained over a month, during which time he visited many prominent vineyards in the Eastern States, on Kelley's Island, in Missouri, and in North Carolina. His investigations not only fully corroborated all my previous conclusions regarding the Phylloxera, but gave him a knowledge of the quality of our native grapes and wines which will be very apt to dispel much of the prejudice against them that has so universally possessed his countrymen, who have not followed our recent rapid progress in viticulture and viniculture, but found their opinions on the inferior results which attended the infancy of those industries in America. Such, in brief, is the history of the grape Phylloxera. Let us now take a closer insight into the nature of the insect.

The genus *Phylloxera* is characterized by having three-jointed an-

tennæ, the third or terminal much the longest, and by carrying its wings overlapping flat on the back instead of roof-fashion. It belongs to the whole-winged bugs (*Homoptera*), and osculates between two great families of that sub-order, the plant-lice (*Aphididæ*) on the one hand and the bark-lice (*Coccidæ*) on the other. In the one-jointed tarsus of the larva or newly-hatched louse, and in being always oviparous, it shows its affinities with the latter family; but in the two-jointed tarsus of the more mature individuals, and in all other characters, it is essentially aphididan. "In every department of natural history a species is occasionally found which forms the connecting link between two genera, rendering it doubtful under which genus it should properly be arranged. Under such circumstances the naturalist is obliged to ascertain by careful examination the various predominating characteristics, and finally place it under the genus to which it bears the closest affinity in all its details." So wrote Audubon and Bachman twenty-eight years ago;[1] and what is true of genera is equally true of species, families, and of still higher groups. In the deepest sense all Nature is a whole, and all her multitudinous forms of animal and vegetal life are so closely interlinked, and graduate into each other so insensibly, that in founding divisions on too trivial differences we subvert the objects of classification. Thus, instead of founding a new family for this insect, as Dr. Shimer did, and as there seems a tendency on the part of others to do, it is both more consonant with previous custom, and more sensible in every way, to retain it among the *Aphididæ*.

BIOLOGICAL.

DIFFERENT FORMS WHICH THE INSECT ASSUMES.—Not the least interesting features in the economy of our Phylloxera are the different phases or forms under which it presents itself. Among these forms are two constant types which have led many to suppose that we have to do with two species. The one type, which I have, for convenience, called *gallæcola*, lives in galls on the leaves; the other, which I have called *radicicola*, on swellings of the roots. The subjoined table will assist to a clear understanding of what follows.

Type 1. *Gallæcola.* (*Vitifoliæ*, Fitch. Fig. 3, *f*, *g*, *h*.)
Type 2. *Radicicola.*—
α, Degraded or Wingless Form. (Fig. 4, *e*, *f*, *g*.)
β, Perfect or Winged Form. (Fig. 5, *g*, *h*; Fig. 7, *b*.)

TYPE GALLÆCOLA OR GALL-INHABITING.—The gall or excrescence produced by this insect is simply a fleshy swelling of the under side of the leaf, more or less wrinkled and hairy, with a corresponding depression of the upper side, the margin of the cup being fuzzy, and drawn together so as to form a fimbriated mouth. It is usually cup-shaped, but sometimes greatly elongated or purse-shaped (Fig. 2, *a*, *b*).

[1] "Quadrupeds of North America," vol. i., p. 215.

Soon after the first vine-leaves that put out in the spring have fully expanded, a few scattering galls may be found, mostly on the lower leaves, nearest the ground. These vernal galls are usually large (of the size of an ordinary pea), and the normal green is often blushed with rose where exposed to the light of the sun. On opening one of them (Fig. 3, *d*) we shall find the mother-louse diligently at work sur-

FIG. 1.

LEAF COVERED WITH GALLS.

rounding herself with pale-yellow eggs of an elongate oval form, scarcely .01 inch long, and not quite half as thick (Fig. 3, *c*). She is about .04 inch long, generally spherical in shape, of a dull orange-color, and looks not unlike an immature seed of the common purslane. At times, by the elongation of the abdomen, the shape assumes, more or less perfectly, the pyriform. Her members are all dusky, and so

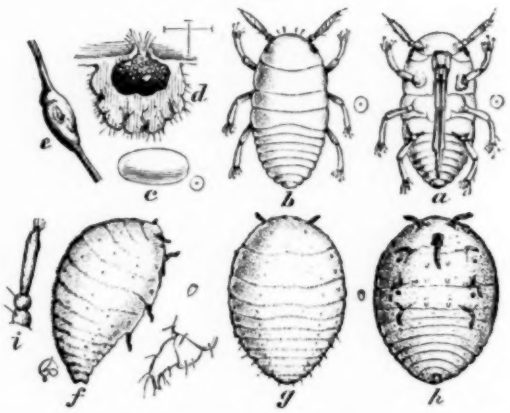
FIG. 2.

a and *b*, elongated galls; *c* and *d*, upper and under side of abortive galls.

short compared to her swollen body, that she appears very clumsy, and undoubtedly would be outside of her gall, which she never has occasion to quit, and which serves her alike as dwelling-house and coffin. The eggs begin to hatch, when six or eight days old, into active little oval, hexapod beings, which differ from their mother in their brighter yellow color and more perfect legs and antennæ, the tarsi being furnished with long, pliant hairs, terminating in a more or less distinct globule. These hairs were called *digituli* by Dr. Shimer, and

they lose their globular tips and become more or less worn with age. Issuing from the mouth of the gall, these young lice scatter over the vine, most of them finding their way to the tender terminal leaves, where they settle in the downy bed which the tomentose nature of these leaves affords, and commence pumping up and appropriating the sap. The tongue-sheath is blunt and heavy, but the tongue proper—consisting of three brown, elastic, and wiry filaments, which, united, make so fine a thread as scarcely to be visible with the strongest microscope—is sharp, and easily run under the parenchyma of the leaf. Its puncture causes a curious change in the tissues of the leaf, the

FIG. 3.



TYPE GALL-ÆCOLA.—*a*, *b*, newly-hatched larva, ventral and dorsal view; *c*, egg; *d*, section of gall; *e*, swelling of tendril; *f*, *g*, *h*, mother gall-louse—lateral, dorsal, and ventral views; *i*, her antenna; *j*, her two-jointed tarsus. Natural sizes indicated at sides.

growth being so stimulated that the under side bulges and thickens, while the down on the upper side increases in a circle around the louse, and finally hides and covers it as it recedes more and more within the deepening cavity. Sometimes the lice are so crowded that two occupy the same gall. If, from the premature death of the louse, or other cause, the gall becomes abortive before being completed, then the circle of thickened down or fuzz enlarges with the expansion of the leaf, and remains (Fig. 2, *c*) to tell the tale of the futile effort. Otherwise, in a few days the gall is formed, and the inheld louse, which, while eating its way into house and home, was also growing apace, begins a parthenogenetic maternity by the deposition of fertile eggs, as her immediate parent had done before. She increases in bulk with pregnancy, and one egg follows another in quick succession, until the gall is crowded. The mother dies and shrivels, and the young, as they hatch, issue and found new galls. This process continues during the summer until the fifth or sixth generation. Every egg brings forth a fertile female, which soon becomes wonderfully prolific. The

number of eggs found in a single gall averages about 200; yet it will sometimes reach as many as 500, and, if Dr. Shimer's observations can be relied on, it may even reach 5,000.[1] I have never found any such number myself; but, even supposing there are but five generations during the year, and taking the lowest of the above figures, the immense prolificacy of the species becomes manifest. Small as the animal is, the product of a single year, even at this low estimate, would encircle the earth over thirty times if placed in a continuous line, each individual touching the end of another. Well it is for us that they are not permitted to multiply in this geometrical ratio! Nevertheless, as summer advances, they do frequently become prodigiously multiplied, completely covering the leaves with their galls, and settling on the tendrils, leaf-stalks, and tender branches, where they also form knots and rounded excrescences (Fig. 3, *e*), much resembling those made on the roots. In such a case, the vine loses its leaves prematurely. Usually, however, the natural enemies of the louse seriously reduce its numbers by the time the vine ceases its growth in the fall, and the few remaining lice, finding no more succulent and suitable leaves, seek the roots. Thus, by the end of September, the galls are mostly deserted, and those which are left are almost always infested with mildew (*Botrytis viticola*, Berkely), and eventually turn brown and decay. On the roots, the young lice attach themselves singly or in little groups, and thus hibernate. The male gall-louse has never been seen, and there is every reason to believe that he has no existence. Nor does the female ever acquire wings. Indeed, I cannot lay too much stress on the fact that *gallæcola* occurs only as an agamic and apterous female form. It is but a transient summer state, not at all essential to the perpetuation of the species. I have found it occasionally on all species of the Grape-vine (*vinifera*, *riparia*, *æstivalis*, and *Labrusca*) cultivated in the Eastern and Middle States, and on the wild *Cordifolia;* but it flourishes only on the River-bank grape (*riparia*), and more especially on the Clinton and Taylor, with their close allies. Thus, while legions of the root-inhabiting type (*radicicola*) are overrunning and devastating the vineyards of France, this *gallæcola* is almost unknown there, except on such American varieties as it infests with us. A few of its galls have been found at Sorgues, on a variety called Tinto; and others have been noticed on *vinifera* vines interlocking infested American vines, or have been produced by purposed contact with the young *gallæcola.* Similarly, there are many varieties, especially of *Labrusca*, which, in this country, suffer in the roots, and never show a gall on the leaves.

The precise conditions which determine the production and multiplication of *gallæcola* cannot now, if they ever can, be stated; but it is quite evident that the nature and constitution of the vine are important elements, since such vines as the Herbemont often bear

[1] "Practical Entomologist," vol. i., p. 17.

witness, by their leaves covered with abortive galls, to the futile efforts the lice sometimes persist in making to build in uncongenial places.

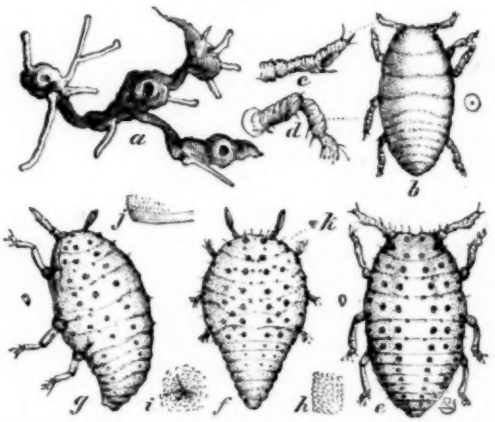
Yet other elements come into play, and nothing strikes the observer as more curious and puzzling than the transitory nature of these galls, and the manner in which they are found—now on one variety, now on another.

I was formerly inclined to believe that *gallæcola* was a necessary phase in the annual cycle of the insect's mutations; in other words, that it was essential to the continuance of the species, and was probably the product of the egg laid by the winged and impregnated female. On this hypothesis I imagined that *gallæcola* was probably the invariable precursor of *radicicola* in an uninfested vineyard, and that, if galls were not allowed to develop in such a vineyard, it would not suffer from root-lice. More extensive experience has satisfied me that the hypothesis is essentially erroneous, and that, while the first galls may sometimes be produced by lice hatched from the few eggs deposited above-ground by the winged female, they are more often formed by young lice hatched on the roots, and which, wandering away from their earthy recesses, are fortunate enough to find suitable leaf conditions. It is barely possible that under certain circumstances, as, for instance, on our wild-vines, where the soil around the roots is hard and compact, *gallæcola* may become more persistent, and pass through all the phases belonging to the species without descending to the roots—the eggs wintering on the ground, or the young under the loose bark, or upon the canes. For a somewhat similar state of things actually takes place with another plant-louse (*Eriosoma pyri*, Fitch), which in the Western United States normally inhabits the roots of our apple-trees, and only exceptionally the branches; while in the moister Atlantic States, and in England and moister parts of Europe, where it was introduced from this country, it normally infests the branches, and more exceptionally the roots. But there are no facts yet known to prove such to be the case with the Grape Phylloxera, even on our wild-vines, and I do not believe that it ever is the case in our cultivated vineyards.

As already indicated, the autumnal individuals of *gallæcola* descend to the roots, and there hibernate. There is every reason to believe also that, throughout the summer, some of the young lice hatched in the galls are passing on to the roots; as, considering their size, they are great travelers, and show a strong predisposition to drop, their natural lightness, as in the case of the young *Cicada*, and of other insects which hatch above but live under ground, enabling them thus to reach the earth with ease and safety. At all events, I know, from experiment, that the young *gallæcola*, if confined to vines on which they do not normally, and perhaps cannot, form galls, will, in the middle of summer, make themselves perfectly at home on the roots.

TYPE RADICICOLA OR ROOT-INHABITING.—We have seen that, in all probability, *gallæcola* exists only in the apterous, shagreened, non-tubercled, fecund female form. *Radicicola*, however, presents itself in two principal forms. The newly-hatched larvæ of this type are undistinguishable, in all essential characters, from those hatched in the galls; but in due time they shed the smooth larval skin, and acquire raised warts or tubercles which at once distinguish them from *gallæcola*. In the development from this point two forms are separable with sufficient ease, one (*α*) of a more dingy greenish-yellow, with more swollen fore-body, and more tapering abdomen; the other (*β*) of a brighter yellow, with the lateral outline more perfectly oval, and with the abdomen more truncated at tip.

FIG. 4.



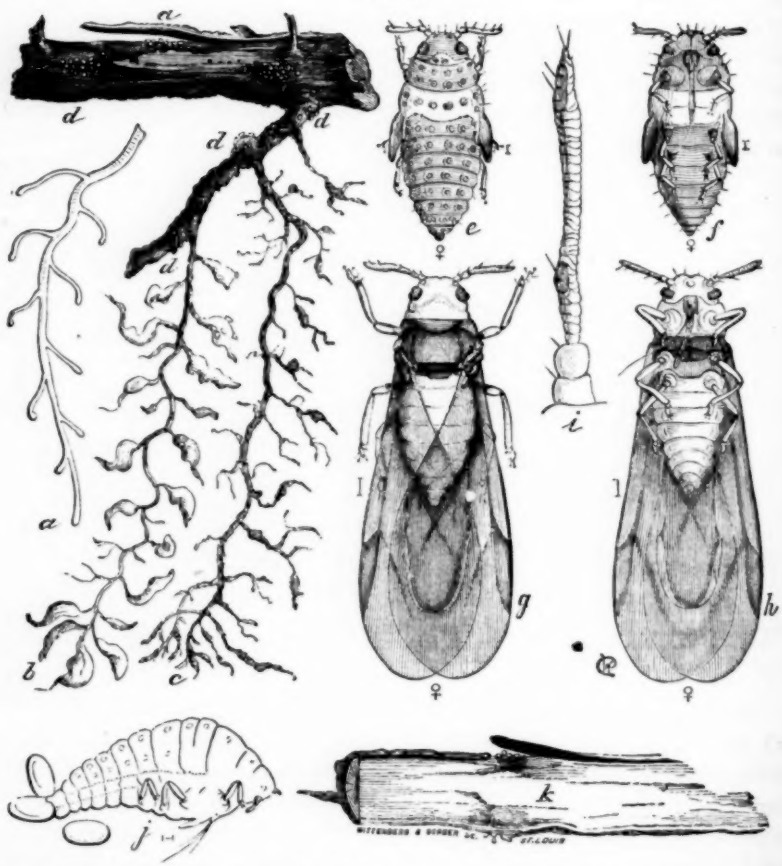
TYPE RADICICOLA.—*a*, roots of Clinton vine, showing relation of swellings to leaf-galls, and power of resisting decomposition; *b*, larva as it appears when hibernating; *c*, *d*, antenna and leg of same; *e*, *f*, *g*, forms of more mature lice.

The first or mother form (Fig. 4, *f*, *g*) is the analogue of *gallæcola*, as it never acquires wings, and is occupied, from adolescence till death, with the laying of eggs, which are less numerous and somewhat larger than those found in the galls. I have counted in the spring as many as 265 eggs in a single cluster, and all evidently from one mother, who was yet very plump and still occupied in laying. As a rule, however, they are less numerous. With pregnancy this form becomes quite tumid and more or less pyriform, and is content to remain with scarcely any motions in the more secluded parts of the roots, such as the creases, sutures, and depressions, which the knots afford. The skin is distinctly shagreened (Fig. 4, *h*), as in *gallæcola*. The warts, though usually quite visible with a good lens, are at other times more or less obsolete, especially on the abdomen. The eyes, which were quite perfect in the larva, become more simple with each moult, until they consist, as in *gallæcola*, of but triple eyelets (Fig. 4, *k*), and, in the general structure, this form becomes more degraded with maturity,

wherein it shows the affinity of the species to the *Coccidæ*, the females of which, as they mature, generally lose all trace of the members they possessed when born.

The second or more oval form (Fig. 4, *e*) is destined to become winged. Its tubercles, when once acquired, are always conspicuous;

FIG. 5.

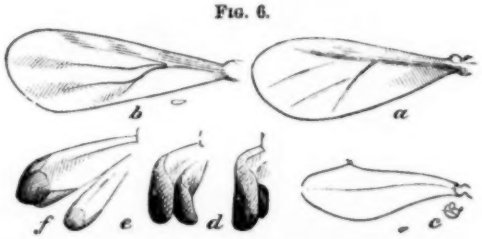


TYPE RADICICOLA.—*a*, shows a healthy root; *b*, one on which the lice are working, representing the knots and swellings caused by their punctures; *c*, a root that has been deserted by them, and where the rootlets have commenced to decay; *d*, *d*, *d*, show how the lice are found on the larger roots; *e*, female pupa, dorsal view; *f*, same, ventral view; *g*, winged female, dorsal view; *h*, same, ventral view; *i*, magnified antenna of winged insect; *j*, side view of the wingless female, laying eggs on roots; *k*, shows how the punctures of the lice cause the larger roots to rot.

it is more active than the other, and its eyes increase rather than diminish in complexity with age. From the time it is one-third grown, the little dusky wing-pads may be discovered, though less conspicuous than in the pupa state, which is soon after assumed. The pupæ (Fig. 5, *e*, *f*) are still more active, and, after feeding a short time, they make

their way to the light of day, crawl over the ground and over the vines, and finally shed their last skin and assume the winged state. In this last moult the tubercled skin splits on the back, and is soon worked off, the body in the winged insect having neither tubercles nor granulations. These winged insects are most abundant in August and September, but may be found as early as the first of July, and until the vines cease growing in the fall. The majority of them are females, with the abdomen large, and more or less elongate. The veins of the front wing are not connected (Fig. 6, *a*), and, by virtue of the large abdomen, the body appears somewhat constricted behind the thorax. From two to five eggs may invariably be found in the abdomen of these, and are easily seen when the insect is held between the light, or mounted in balsam or glycerine. A certain proportion have an entirely different shaped and smaller body, the abdomen being short, contracted, and terminating in a fleshy and dusky penis-like protuberance, the limbs stouter, and the wings proportionally larger and stouter, with

FIG. 6.



PTEROGOSTIC CHARACTERS.—*a*, *b*, different venation of front-wing; *c*, hind-wing; *d*, *e*, *f*, showing development of wings.

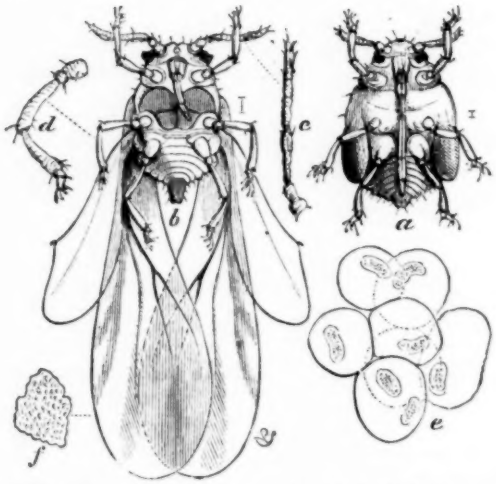
their veins connecting (Fig. 6, *b*). This shorter form (Fig. 7, *b*) never has eggs in the abdomen, but, instead, a number of vesicles (Fig. 7, *e*), containing granulations in sacs. These granulations have much the appearance of spermatozoa, and seem to have a Brownian movement, but are without tails.

This form has been looked upon as the male by myself, Planchon, Lichtenstein, and others. Yet I have never succeeded in witnessing it perform the functions of the male, nor has any one else that I am aware of. The males in all plant-lice are quite rare, and, in the great majority of species, unknown. Where known, this sex bears about the same relation to the female as the shorter and smaller Phylloxera just described does to the larger. These same differences observed in the winged insects obtain in the other species of the genus that are known, and have always been looked upon as sexual. Signoret, an authority on these insects, once so looked upon them,[1] but has lately declared the shorter form to be a female emptied of her eggs. If this be so, then the eggs must be laid before the insect arrives at maturity (a

[1] "Annales de la Société Entomologique de France," 1867, pp. 301, 303.

highly improbable circumstance); for the characteristics which distinguish it are to be noticed in the pupa (Fig. 7, *a*), which is almost as broad as long, with very large wing-pads and strong limbs; while the winged insect does not, as we have seen, carry any eggs. But, whatever the true nature and functions of these problematic and gynandrous individuals, it would seem, from some exceedingly interesting observations lately made by Balbiani,[1] that they cannot be males, if there be any such thing as unity of habit and character among the species of the genus. Balbiani has made the curious discovery, in the annual development of *Phylloxera quercus*, that the winged individuals, which appear in August, fly off to new leaves and deposit their

FIG. 7.



TYPE RADICICOLA.— *a*, *b*, pupa and imago of a gynandrous individual, or supposed male; *c*, *d*, its antenna and leg; *e*, vesicles found in abdomen.

unimpregnated eggs, to the number of five to eight. These eggs are of two different sizes, the smaller being readily separated from the larger. They hatch in about a dozen days, the smaller giving birth to males, and the larger to females, which have neither mouth-parts nor digestive organs, and neither grow nor moult after birth. The sole aim of their existence is the reproduction of the species, and they crawl actively about and gather in little multitudes in the crevices and interstices which are afforded them. The male, except in size, seems to differ from the female only in having a small conical tubercle, which serves as sexual organ. Coitus lasts but a few minutes, and the same male may serve several females. Four or five days after birth the female lays a solitary egg, which, increasing somewhat after impregnation, had caused her abdomen to swell and enlarge a little prior to

[1] "Comptes Rendus de l'Académie des Sciences de Paris," 1873, p. 884.

oviposition. Two or three days after this operation the mother dies; but the males live as long again.

This solitary egg, which Balbiani calls the winter-egg, soon takes on a dark color, which indicates its fecundity and distinguishes it from parthenogenetic eggs of both the winged and wingless females. It is surmised that this egg passes the winter to give birth in spring to the form destined to recommence the cycle of development belonging to the species.

These discoveries are truly remarkable, and appear to me all the more so since Balbiani[1] likewise found that the individuals which never become winged attain maturity without laying eggs on the leaves on which they were born, but crawl on to the branches and in the interstices of the old scales at the base of the new year's growth. There they lay a number of eggs, *which are absolutely like those deposited by the winged females, and, like them, produce the sexual individuals, i. e., both males and females.* Now, this does not correspond with what I have seen myself of the species, or with what has been described by others; for the apterous individuals of *quercus* surround themselves with eggs on the leaves where they are born.

M. Max-Cornu has already announced having found a sexual individual, without mouth-parts, of the Grape Phylloxera; and it is quite likely, now that Balbiani has paved the way, that we shall next year have its natural history complete. But whether the Grape Phylloxera produces this fecundated and solitary egg or not, such an egg is neither essential to its winter life, nor to that of an American species (*Phylloxera Rileyi* Lichtenstein), which will be described farther on, and which is, in every respect, very closely allied to the European *quercus*.

While, therefore, there is much yet to learn in the life-history of our Grape Phylloxera, the facts which I have already unequivocally stated, as well as those which I shall now proceed to give, remain indisputable, and do not seem fully to accord with Balbiani's discoveries.

As fall advances the winged individuals become more and more scarce, and as winter sets in only eggs, newly-hatched larvæ, and a few apterous egg-bearing mothers, are seen. These last die and disappear during the winter, which is mostly passed in the larva state, with here and there a few eggs. The larvæ thus hibernating (Fig 4, *b*) become dingy, with the body and limbs more shagreened and the claws and *digituli* less perfect than when first hatched; and, of thousands examined, all bear the same appearance and all are furnished with strong suckers. As soon as the ground thaws and the sap starts in the spring, these young lice work off their winter coat, and, growing apace, commence to deposit eggs. All, without exception, so far as I have seen,[2] become mothers and assume the degraded form (*a*) already described.

[1] *Auctore* Dr. Fr. Cazalis, as reported in the *Messager du Midi*, November 16, 1873.

[2] I have examined thousands in the vineyard in early spring, and other thousands reared artificially in a warm room in winter.

At this season of the year, with the exuberant juices of the plant, the swellings on the roots are large and succulent and the lice plump to repletion. One generation of the mother form (*a*) follows another—fertility increasing with the increasing heat and luxuriance of summer—until at least the third or fourth has been reached before the winged form (*β*) makes its appearance in the latter part of June or early in July.

Such are the main features which the development of the insect presents to one who has studied it in the field as well as in the closet.

This polymorphism, which at first strikes us as singular, is quite common among plant-lice, and many curious instances of still more striking character might be given. Even the differences themselves, between *gallæcola* and *radicicola* are more apparent than real. Individuals of the latter are often met with, which, in the comparative obsoleteness of their tubercles, are almost undistinguishable from the former; and the tubercles, like many other purely dermal appurtenances, are of an evanescent and unimportant character. Many insect larvæ, which are normally granulated with papillæ, not unfrequently have these more or less obsolete, and at some stages of growth have the skin absolutely smooth. The same thing holds true of tubercles, which, as in the case of the Imported Currant-worm (*Nematus ventricosus* Klug), are often completely cast off at a moult. In *Phylloxera* they are very variable in size, as we shall see, in *Rileyi;* and in *quercus*, according to several reliable authors, the tubercles which are characteristic of the species in Southern France are entirely wanting around Paris. If we carefully study them in *vastatrix* we shall find that they consist of points where the granulated skin is gathered around a fleshy hair in little rugosities, and becomes darker (Fig. 4, *i*). They do not occur in the newly-hatched larva, are not visible immediately after each moult, and are lost again in the winged individuals. In the form *gallæcola* we shall find, upon careful examination, especially of the exuvia, that, as Max-Cornu has shown, there are rows of these short hairs, scarcely extending beyond the natural granulations and corresponding to those on the tubercles of *radicicola*. These hairs are more visible on the younger and smoother lice, after the first moult; and they are sometimes so stout, particularly on the abdomen, as to remind one of those on *Rileyi*, to be described. The ventral characteristics of the two types are identical.

Since I proved, in 1870, the absolute identity of these two types by showing that the gall-lice become root-lice, the fact has been repeatedly substantiated by different observers. Yet, strange to say, no one has heretofore succeeded in making gall-lice of the young hatched on the roots, though I formerly supposed that Signoret had done so. It is, therefore, with much satisfaction that I record the fact of having succeeded this winter in obtaining galls on a young Clinton vine from young *radicicola*, and of thus establishing beyond peradventure the

specific interrelation and identity of the two types. I make this announcement with all the more pleasure, that for three years past, both on vines growing out-doors and in pots in-doors, I had in vain attempted to obtain the same result.

PRACTICAL CONSIDERATIONS.

THE MORE MANIFEST AND EXTERNAL EFFECTS OF THE PHYLLOXERA DISEASE.—The result which follows the puncture of the root-louse is an abnormal swelling, differing in form according to the particular part and texture of the root. These swellings, which are generally commenced at the tips of the rootlets, where there is excess of plasmatic and albuminous matter,[1] eventually rot, and the lice forsake them and betake themselves to fresh ones—the living tissue being necessary to the existence of this as of all plant-lice. The decay affects the parts adjacent to the swellings, and on the more fibrous roots cuts off the supply of sap to all parts beyond. As these last decompose, the lice congregate on the larger ones, until at last the root-system literally wastes away.

During the first year of attack there are scarcely any outward manifestations of disease, though the fibrous roots, if examined, will be found covered with nodosities, particularly in the latter part of the growing season. The disease is then in its incipient stage. The second year all these fibrous roots vanish, and the lice not only prevent the formation of new ones, but, as just stated, settle on the larger roots, which they injure by causing hypertrophy of the parts punctured, which also eventually become disorganized and rot. At this stage the outward symptoms of the disease first become manifest, in a sickly, yellowish appearance of the leaf and a reduced growth of cane. As the roots continue to decay, these symptoms become more acute, until by about the third year the vine dies. Such is the course of the malady on vines of the species *vinifera*, when circumstances are favorable to the increase of the pest. When the vine is about dying it is generally impossible to discover the cause of the death, the lice, which had been so numerous the first and second years of invasion, having left for fresh pasturage.

MODE OF SPREADING.—The gall-lice can only spread by traveling, when newly hatched, from one vine to another; and, if this slow mode of progression were the only one which the species is capable of, the disease would be comparatively harmless. The root-lice, however, not only travel underground along the interlocking roots of adjacent vines, but crawl actively over the surface of the ground, or wing their way from vine to vine, and from vineyard to vineyard. Doubts have repeatedly been expressed by European writers as to the power

[1] For a very minute and careful study of the pathological characteristics of these swellings the reader may refer to Max-Cornu's excellent papers in the *Comptes Rendus*, for 1873, of the Paris Académie des Sciences.

of such a delicate and frail-winged fly to traverse the air to any great distance. "On a calm, clear day, the latter part of last June, it was my fortune to witness a closely-allied species (*Phylloxera caryæfoliæ* Fitch), of the same size and proportions, swarming on the wing to such an extent that to look against the sun revealed them as a myriad silver specula. They settled on my clothing by dozens, and any substance in the vicinity that was the least sticky was covered with them. With such a sight before one's eyes, and with full knowledge of the prolificacy of these lice, it required no effort to understand the fearful rapidity at which the Phylloxera disease has spread in France, or the epidemic nature it has assumed. Imagine such swarms, mostly composed of egg-bearing females, slowly drifting, or more rapidly blown, from vineyard to vineyard; imagine them settling upon the vines and depositing their eggs, which give birth to fecund females, whose progeny in five generations, and probably in a single season, may be numbered by billions, and you have a plague (should there be no conditions to prevent that increase) which, though almost invisible and easily unnoticed, may become as blasting as the plagues of Egypt."[1]

Since the above-quoted passage was written, I have fully proved the same ability to fly in the winged grape-root lice, and am satisfied that they can sustain flight for a considerable time under favorable conditions, and, with the assistance of the wind, they may be wafted to great distances. These winged females are much more numerous in the fall of the year than has been supposed by entomologists. Wherever they settle, the few eggs which each carries are sufficient to perpetuate the species, and thus spread the disease, which, in the fullest sense, may be called contagious. Whether in a state of nature these winged females show a preference for any one part of the vine in the consignment of their eggs, is not yet known. It is quite certain, however, that they do not reënter the ground. Neither do we know whether—in the light of Balbiani's discoveries regarding the European Oak Phylloxera—the young hatching from these eggs produce the diminutive sexual individuals already described. In confinement I have had such eggs deposited both on the leaves and on the buds, and from the preference which, in ovipositing, these aërial mothers showed for little balls of cotton placed in the corners of their cages, I infer that the more tomentose portions of the vine, such as the bud, or the base of a leaf-stem, furnish the most appropriate and desirable *nidi*. On this hypothesis it is quite possible for the insect to be introduced from vineyard to vineyard, or from country to country, as well upon cuttings as upon roots.

[1] "Entomological Report of Missouri," vol. v., pp. 72, 73.

THE LIMITS OF OUR KNOWLEDGE OF NATURE.

By Professor EMIL DU BOIS-REYMOND,[1]
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TRANSLATED FROM THE GERMAN, BY J. FITZGERALD, A. M.

JUST as a world-conqueror of ancient times, as he halts for a day in the midst of his victorious career, might long to see the boundaries of the vast territories he has subjugated more clearly defined, so that here he may levy tribute of some nation hitherto exempt, or that there he may discern some natural barrier that cannot be overcome by his horsemen, and which constitutes the true limit of his power, in like manner it will not be out of place, if Natural Science, the world-conqueror of our times, resting as on a festive occasion from her labor, should strive to define the true boundaries of her immense domain. And this undertaking I hold to be all the more legitimate, because I believe there exist two widely-diffused errors with regard to the limits of natural science, and because I think it possible that from the study of such a question, despite its apparent triviality, some advantage might be derived even by those who do not at all share in the errors of which I speak.

Hence I propose to investigate the limits of natural science; and first I must say what natural science is.

Natural science—or, more definitely, knowledge of the physical world with the aid of and in the sense of theoretical natural science—means the reduction of all change in the physical world to movements of atoms produced independently of time by their central forces; or, in other words, natural science is the resolution of natural processes into the mechanics of atoms. It is a fact of psychological experience that, where such a resolution is practicable, our desire of tracing things back to their causes is provisionally satisfied. The propositions of mechanics are mathematically presentable, and have in themselves the same apodictic certainty as the propositions of mathematics. As the changes of the physical world are reduced to a constant sum of potential and kinetic energy, which is inseparable from a constant quantity of matter, there remains in these changes themselves nothing further that needs explanation.

What Kant says in the introduction to his "Metaphysical Elements of Natural Science," viz., that "in each special natural science the amount of science, properly so called, is equal to the amount of mathematics it contains"—must, therefore, be further narrowed down, and instead of mathematics we must read atomic mechanics. Plainly this

[1] An Address delivered at the Forty-fifth Congress of German Naturalists and Physicians at Leipsic.

was Kant's own meaning, when he withheld from chemistry the title of science, and relegated it among *experimental* sciences. It is not a little noteworthy that in our own times chemistry, being forced, by the discovery of the doctrine of substitution, to surrender electro-chemical dualism, has been apparently still further removed from the grade of a science, in this sense of the word.

If we were to suppose all changes in the physical world resolved into atomic motions, produced by constant central forces, then we should know the universe scientifically. The condition of the world at any given moment would then appear to be the direct result of its condition in the preceding moment, and the direct cause of its condition in the subsequent moment. Law and chance would be only different names for mechanical necessity. Nay, we may conceive of a degree of natural science wherein the whole process of the universe might be represented by one mathematical formula, by one infinite system of simultaneous differential equations, which should give the location, the direction of movement, and the velocity, of each atom in the universe at each instant. "A mind," says Laplace, "which at a given instant should know all the forces acting in Nature, as also the respective situation of the beings of which it consists, provided its powers were sufficiently vast to analyze all these data, could embrace in one formula the movements of the largest bodies in the universe, and those of the smallest atom; nothing would be uncertain for such a mind, and the future, like the past, would be present to its eyes. The human intellect offers, in the perfection to which it has brought astronomy, a faint idea of what such a mind would be."

Indeed, just as in lunar equations the astronomer need give but a negative value to time, in order to determine whether, when Pericles embarked for Epidaurus, the sun was eclipsed for the Piræus, so could the mind imagined by Laplace, by suitable application of its universal formula, tell us who was the Man in the Iron Mask, or how the President was lost. As the astronomer foretells the day whereon years hence a comet emerges again out of the depths of space into the heavens, so could that mind by its equations determine the day whereon the Greek cross shall glitter from the mosque of St. Sophia, or when England shall have consumed the last of her coals. If in his universal formula he set down $t=-\infty$, he could discover the mysterious primeval condition of all things. He would in the boundless space see matter already in motion, or unequally distributed, for, were the distribution equable, there could never be disturbance of equilibrium. Suppose he lets t grow *ad infinitum* in the positive sense, then he could tell whether Carnot's theorem threatens the universe with icy immobility in finite or only in infinite time. For such a mind the hairs of our heads would be numbered, and without his knowledge no sparrow could fall to the ground. Being a seer expert both in the past and the future, for him, as D'Alembert, in the Introduction to the Ency-

clopædia, expressed it, giving utterance to the germ of Laplace's thought, "the universe would be one single fact and one great truth."

In Leibnitz, too, we find Laplace's thought, and even better developed in some measure than in Laplace himself, inasmuch as Leibnitz conceives of this mind as being endowed with senses and with technical powers of corresponding perfection. Bayle brought against the doctrine of Preëstablished Harmony the objection that it supposes the human body to be like a vessel that makes for its harbor by means of its own forces; Leibnitz replied that this is not so impossible as Bayle holds it to be. "There is no doubt," says he, "that a man might construct a machine that could for some time move about in a city, and turn accurately at certain street-corners. An incomparably more perfect, though still finite mind, might foresee and obviate an incomparably greater number of obstacles. So true is this, that if the world is, as some suppose, only a compound of a finite number of atoms, which move in accordance with the laws of mechanics, it. is certain that a finite mind might be elevated sufficiently to comprehend and to foresee with mathematical certitude whatsoever is to occur therein within a given time. And thus this mind could not only construct a ship capable of making a given port by itself, provided the proper force and direction were supplied, but it could even construct a body capable of imitating the actions of man."

It need not be said that the human mind will ever remain very remote from this degree of acquaintance with Nature. To show how far we are from even the beginnings of such knowledge, we need but make one observation. Before our differential equations could be brought into the universal formula, all natural facts would have to be reduced to the motions of a substantially undifferentiated and consequently property-less substratum of what appears to us as heterogeneous matter: in other words, all quality would have to be explained by the arrangement and the motion of this substratum.

This is entirely in accord with what we know of the senses. It is universally conceded that the sense-organs and the sense-nerves carry to their appropriate cerebral regions, or, as Joh. Müller calls them, "sense-substances" (*Sinnsubstantzen*), a motion that is in all cases ultimately identical. As in the experiment suggested by Bidder and successfully made by Vulpian on the nerves of taste, and those of the muscles of the tongue, the sensory and motor nerves, on being cut across, so heal together that excitation of the one class of fibres is transmitted by the cicatrix to the other class: in like manner, were the experiment possible, fibres from different sets of nerves would blend perfectly together. With the nerves of vision and of hearing severed, and then crossed with each other, we should with the eye hear the lightning-flash as a thunder-clap, and with the ear we should see the thunder as a series of luminous impressions. Sense-perception, therefore, as such, has its rise in the "sense-substances." It is

these substances that translate the identical excitation of all the nerves into sense-perceptions, each set, according to its own nature, acting as carriers of Joh. Müller's "specific energies," and so giving quality. The Mosaic dictum, "There was light," is physiologically false. Light first was when the first red eye-point of an infusorial animal for the first time distinguished light from darkness. In the absence of the sense-substance of sight and hearing, this bright, glowing, resonant world around us would be dark and voiceless.

And voiceless and dark in itself, i. e., property-less, as the universe is on subjective decomposition of the phenomena of sense, so is it also from the mechanical stand-point, gained by objective contemplation. Here, in place of sound and light, we have only the vibrations of a primitive, undifferentiated matter, which here has become ponderable, and there imponderable.

But, however well grounded these views may be in general, nothing, as we may say, has been done toward carrying them out in detail. The philosopher's stone that should transmute into one another the as yet unanalyzed elements, and produce them from a higher element, if not from primeval matter itself, must be discovered before the first conjecture as to the development of apparently heterogeneous, from actually homogeneous matter, becomes possible.

Though the human mind will ever remain very remote from the mind imagined by Laplace, yet this is only a matter of degree, in some measure like the difference between a given ordinate of a curve and another immeasurably greater, though still finite, ordinate of the same curve. We resemble this mind, inasmuch as we conceive of it. We might even ask whether a mind like that of Newton does not differ less from the mind imagined by Laplace, than the mind of an Australian or of a Fuegian savage differs from the mind of Newton. In other words, the impossibility of stating and integrating the differential equations of the universal formula, and of discussing the result, is not fundamental, but rests on the impossibility of getting at the necessary determining facts, and, even where this is possible, of mastering their boundless extension, multiplicity, and complexity.

Thus the knowledge of Nature possessed by the mind imagined by Laplace, represents the highest thinkable grade of our own natural science. Hence we may lay this down as the basis of our inquiry as to the limits of this science. Whatever would remain unknown to such a mind, must be perfectly hidden away from our minds, which are confined within much narrower bounds.

There are two positions where even the mind imagined by Laplace would strive in vain to press on farther, and where we have to stand stock-still.

In the first place we must observe that the knowledge of Nature already spoken of as provisionally satisfying our desire of tracing things to their causes, in reality does no such thing, and is not

knowledge at all. The conception of the world as consisting of minute parts that have always existed, and that are indestructible, and whose central forces produce all motion, is only a sort of substitute for an explanation. As has been remarked, it reduces all changes in the physical world to a constant sum of forces and a constant quantity of matter, and thus leaves in the changes themselves nothing that requires explanation. Given the existence of this constant, we can, in our joy for this new insight, be content for a little while; but soon we long to penetrate deeper, and to comprehend it in its own substance. The result is, as all know, that within certain limits the atomic theory is serviceable, and even indispensable for our physico-mathematical studies, but that when we overtax it, and make demands upon it that it is not intended to meet, then as a corpuscular philosophy it leads to interminable contradictions.

A physical atom, i. e., a mass which, as compared with bodies with which we are acquainted, is held to be infinitesimal, but yet, regardless of its name, ideally divisible, and to which properties or a state of motion is attributed, whereby the behavior of a mass consisting of countless such atoms is explained—such a notion is a fiction quite congruous in itself, and under certain conditions a useful fiction in mathematical physics. But, latterly, atoms have been as far as possible discarded in favor of volume-elements of bodies regarded as continuous.

A philosophical atom, on the other hand, i. e., a presumably indivisible mass of inert and inefficient substratum, from which proceed through vacant space efficient forces, is, on closer consideration, a chimera.

For, if this indivisible, inert, by itself ineffective, substratum is to have any actual existence, it must occupy a certain space, however small; and, in that case, we cannot see how it can be indivisible. Then, too, it can occupy space only on condition that it possesses perfect hardness, i. e., that it resists the intrusion into the same space of any other body, in virtue of a force exerted out to its own limits, though not overstepping them, which excludes all other bodies, and which must therefore be greater than any other given force. Not to mention any of the other difficulties which meet us here, we may observe that the substratum is thus represented as no longer inefficient.

But if with the dynamists we conceive of the substratum as being only the middle point of the central forces, then the substratum does not occupy space, for a point is the very negation of space *in* space. Hence we have nothing from which the central forces spring; nothing that could be inert, like matter.

The idea of forces operating at a distance through vacant space is unthinkable, nay, even self-contradictory; though, since Newton's day, owing to a misunderstanding of his doctrine, and in the face of his express warning, it has been a current conception among investigators of Nature. If with Descartes and Leibnitz we consider all

space as occupied, and all motion produced by transfer to bodies in contact, the origin of motion is indeed reduced to a concept derived from our sense-experiences, but this view has also its difficulties. To mention only one of these, it is impossible in this hypothesis to explain the different densities of bodies from different combinations of a homogeneous original matter.

The origin of these contradictions is readily detected. They have their root in our incapacity to conceive of any thing save what we have experienced by either our external or our internal sense. In our endeavor to analyze the physical world, we start out from the divisibility of matter, the parts being to our eyes something simpler and more primitive than the whole. When in thought we carry on this division of matter *ad infinitum*, we act in perfect accordance with our sense-perceptions, and we meet with no obstacle in the process. But we make no advance whatever toward an understanding of things, since we, in fact, carry over into the region of the minute and the invisible the concepts we obtained in the region of the gross and the visible. Thus it is that we acquire the notion of the physical atom. If now we arbitrarily stop the process of dividing at some point where we are supposed to have reached philosophical atoms, that are indivisible, perfectly hard, and furthermore *per se* inefficient, being merely the carriers of the central forces, we are expecting that a matter which we think of under the concept of matter as known to us should, without the aid of any new principle of explication, develop new primordial properties, to explain the nature of bodies. Thus we commit the error which is manifested in the previously-mentioned contradictions.

No one, that has bestowed any thought on this subject, can fail to acknowledge the transcendental nature of the obstacles that face us here. However we try to evade them, we ever meet them in one form or another. From whatever side we approach them, or under whatsoever cover, they are ever found invincible. The ancient Ionian physical philosophers were no more helpless than we in presence of this difficulty. The natural sciences, with all the progress they have made, have availed naught against it, nor will their future progress be of any greater effect. We shall never know any better than we now do (to use the words of Paul Erman), "*was hier im Raume spukt*," the spectre that haunts the world of matter. For even the mind imagined by Laplace, exalted as it would be high above our own, would in this matter be possessed of no keener insight than ourselves, and hence we despairingly recognize here one of the limitations of our understanding.

But if we turn aside from this primordial limit, and postulate matter and force as understood, then, as we have said, the physical world is intelligible ideally. From the original condition of a revolving nebular sphere, the Kantian hypothesis, as further developed by Helm-

holtz with the aid of the mechanical theory of heat, leads to a conception of the origin of our planetary system. We first see our earth revolving in its orbit as a glowing fluid drop with an atmosphere of undefinable constitution. In the course of immeasurable intervals of time we see it become coated over with a crust of indurating primordial rock; sea and land are divided, eruptions of hot carbonic acid break up the granite, and give material for strata of alkaline earths, and finally the conditions arise under which life became possible.

Where and under what form life first appeared, whether at the bottom of the deep sea, as bathybius protoplasm, or whether with the cooperation of the still excessive ultra-violet solar rays, with still higher pressure of carbonic acid in the atmosphere, who can tell? But Laplace's Mind *could* tell, with the aid of the universal formula. For, when inorganic matter coalesces to form organic matter, there is only a question of motion, of the arrangement of molecules into states of more or less stable equilibrium, and of an exchange of matter produced partly by the tension of the molecules, and partly by motion from without. What distinguishes living from dead matter, the plant and the animal, as considered only in its bodily functions, from the crystal, is just this: in the crystal the matter is in stable equilibrium, while a stream of matter pours through the organic being, and its matter is in a state of more or less perfect dynamic equlibrium, the balance being now positive, again approaching zero, and again negative. Hence, without the interference of extraneous masses and forces, the crystal will remain forever what it is, whereas the organic being depends for its existence on certain exterior conditions, transforms potential into kinetic energy, and *vice versa*, and has a definite duration in time. Thus we see, that though there is no fundamental difference between the forces operating in the crystal and in the organized being, still the two are incommensurable, just as a simple building is incommensurable with a factory into which coal, water, and raw material pass, on this side, while at the other side carbonic acid, water, vapor, smoke, ashes, and the products of the machinery, are sent out. The building we may regard as so made up of parts, each resembling the total result, that, like the crystal, it is separable into like parts; the factory, like the organic being (if we abstract from the cellular constitution of the latter, and the divisibility of sundry organisms), is an Individual.

It is therefore an error to recognize, in the first appearance of living things on the earth, any thing supernatural, or any thing else save an exceedingly difficult mechanical problem. This is one of the two errors to wich I proposed to call attention. The other limit of natural science is not here, any more than in the fact of crystallization. Were we able to create the conditions under which organic beings had their rise, which we are not even able to do for all crystals, then, according to the principle of actualism, we could produce organic

beings now in the same way that they were first produced. And even though we never could succeed in observing the original production of organisms—to say nothing of experimenting on it—that fact would constitute no absolute objection to our view. Were matter and force intelligible to us, the world would not cease to be so, even though we should conceive the earth to be covered with the most luxuriant growth of vegetable life, from its emerald equatorial girdle to the last lichen-gray cliffs of the pole; and it would remain equally so, whatever share in the formation of the vegetable world we might concede to the laws of organic development, or to natural selection.

But, for reasons which will readily appear, we must leave out of view, in the present consideration, the now well-known indispensable aid rendered by insects in the fertilization of plants. For the rest, the grandest picture ever sketched of a primeval forest in the tropics by Bernardin de St. Pierre, Von Humboldt, or Pöppig, offers to the view of theoretical science absolutely nothing but matter in motion. This, I think, is the new and very simple form that can be given to the argument against "life-force," in the sense of the vitalists.

But now there comes in, at some point in the development of life upon the earth which we cannot ascertain—the ascertainment of which does not concern us here—something new and extraordinary; something incomprehensible, again, as was the case with the essence of matter and force. The thread of intelligence, which stretches back into negatively-infinite time, is broken, and our natural science comes to a chasm across which is no bridge, over which no pinion can carry us: we are here at the other limit of our understanding.

This other incomprehensible is consciousness. I will now, conclusively as I believe, prove that not only is consciousness unexplainable by its material conditions in the present status of science, which every one will readily admit, but that, even in the nature of things, it never can be explained by these conditions. The contrary opinion, that we must not give up all hope of getting at consciousness from its material conditions, and that in the course of hundreds or thousands of years the mind of man, having invaded now unthought-of realms of knowledge, might succeed where we fail—this is the other error which I propose to combat here.

I use the term "consciousness" designedly, the question here being only as to the fact of an intellectual phenomenon, of any kind whatsoever, even of the lowest grade. There is no need to think of Watt, engrossed with his parallelogram, nor of Shakespeare, Raffaelle, or Mozart, engaged in producing their grand creations, in order to have an instance of a mental fact unexplainable by its material conditions. Just as the most powerful and best developed muscular performance of man or animal is in fact no more obscure than the simple contraction of a single muscle—as the single secretory cell involves the whole problem of secretion—so the most exalted mental activity

is no more incomprehensible in its material conditions than is the first grade of consciousness, i. e., sensation. With the first awakening of pleasure or pain, experienced on earth by some creature of the simplest structure, appeared that impassable gulf, and then the world became doubly incomprehensible.

Few subjects have been more perseveringly studied, more written about, or more hotly disputed, than that of the connection between body and soul in man. All the philosophical schools, as also the fathers of the Church, have had their own opinions upon this matter. The more recent philosophy is less concerned with this question; but its beginnings in the seventeenth century abounded in theories of the interaction of matter and mind.

Two hypotheses set up by Descartes shut off that philosopher from all possibility of understanding this interaction. First, he held that body and soul are two different substances, united by God's omnipotence, and that, since the soul has no extension, they can come into contact only at one point, to wit, in the so-called pineal gland of the brain. He held, secondly, that the quantity of motion in the universe is constant. The more clearly it seems to follow from this that the soul cannot produce motion in matter, the more amazed are we on seeing Descartes, in order to save free-will, represent the soul as simply producing motion in the pineal gland, in such a way that the animal spirits, or, as we would say, the nervous principle, may flow out to the appropriate muscles. Conversely, the animal spirits, excited by sense-impressions, give motion to the pineal gland, and then the soul, which is in association with the latter, notes the motion.

Descartes's immediate followers, Clauberg, Malebranche, Geulincx, endeavored to correct this patent error. They insist upon the impossibility of interaction between mind and matter, as being two distinct substances. But, in order to understand how the soul nevertheless moves the body, and is moved by it, they suppose that the soul's willing is the occasion for God each time moving the body in harmony with the soul's desire. Conversely, sense-impressions give occasion to God to modify the soul in conformity with themselves. The *causa efficiens*, therefore, of the changes in the body wrought by the soul, and *vice versa*, is always God, and the soul's willing and the sense-impressions are but the *causæ occasionales* of the perpetually-renewed interventions of Omnipotence.

Finally, Leibnitz explained this problem on the hypothesis, originated, as it would appear, by Geulincx, of body and soul resembling two watches, with synchronous movement. This, says he, may occur in three ways: 1. The two watches might so influence one another by means of oscillations, conveyed to a common attachment, that their movements should be synchronous, as was observed by Huyghens, and as was exemplified, in the beginning of the present century, by Breguet, in a contrivance for rendering the action of two watches more

uniform. 2. One of the watches might be constantly regulated, so as to keep it uniform with the other. 3. The watchmaker might be so skillful as to be able to make both go together, though independent of one another. As between body and soul, the first contrivance is clearly impossible. The second, which agrees with the occasionalist doctrine, is unworthy of God, whom it employs as a *Deus ex machinâ*. The third then remains, and here we find again Leibnitz's peculiar doctrine of Preëstablished Harmony.

But these and all similar views are discredited by the more recent investigations of natural science, and are void of all influence in modern thought, by reason of the dualistic principle on which they rest, in conformity to their semi-theological origin. The propounders of these theories start out from the hypothesis of a spiritual substance absolutely diverse from the body, viz., the soul, and their study is to investigate its association with the body. They find that the coupling of these two substances is possible only by a miracle, and that even after this first miracle another association of the two cannot take place except by means of a fresh miracle, or of a continuous miracle, dating from creation. This consequence they give out as a new solution of the problem, though they never took sufficient pains to inquire whether they themselves have not attributed to the soul such a nature that mutual interaction between it and the body is unthinkable. In short, the most satisfactory demonstration of the impossibility of the interaction of soul and body leaves room to question whether the premises were not arbitrary, and whether consciousness may not be regarded as simply the effect of matter, and so perhaps understood. Hence, the student of natural science demands that the argument to show that mental phenomena are unintelligible from their material conditions shall have nothing to do with any hypothesis as to the origin of such phenomena.

Astronomical knowledge of a material system I call such a knowledge of all its parts, their respective positions and their motions, that their position and motion, at any given time, past or future, may be calculated with the same certainty as we calculate the position and motion of the heavenly bodies, by means of previous absolute accuracy of observation and perfection of theory. To get the differential equation whose integration will give the desired results, we need only have, as it were, three positions of the parts of the system; i. e., we must know the position of the parts of the system at three successive instants, separated by two differentials of time. From the difference of the courses run in the equal and infinitesimal periods of time between the three we deduce the forces acting upon the system and within it.

In our incapacity to comprehend matter and force, astronomical knowledge of a material system is the completest knowledge we can expect to acquire of it. With this our instinct of causality is wont to be satisfied, and this is the kind of knowledge that would be possessed

even by the Mind imagined by Laplace, if it made due use of its universal formula.

Now, suppose we had such astronomical knowledge as this, with regard to a muscle, a gland, an electrical organ, or a luminiferous organ in the state of excitation; of a ciliary cell, a plant, an ovum in contact with the sperm, or of a fruit at some stage of its development. In that case we should possess the fullest possible knowledge of these material systems, and our instinct of causality would be so far satisfied that we should desire nothing more, save to know what matter and force themselves are. Muscular contraction, secretion by the gland, the shock of the electrical, and the shining of the luminiferous organ; ciliary action, growth and chemical action of the cell in the plant; impregnation and development of the egg—all these phenomena, now hopelessly obscure, would be as evident for us as the movements of the planets. On the contrary, if we make a like supposition of astronomical knowledge, with regard to the brain of man, or even the soul-organ of the lowest animal, whose mental activity may be restricted to the sensation of pleasure and pain, then, so far as all the material phenomena are concerned, our knowledge would be as perfect, and our instinct of causality as satisfied, as in the case of muscular contraction or secretion, provided we had astronomical knowledge of muscles or glands. The involuntary actions of the centres, and those not necessarily connected with sensation—reflex action, simultaneous action, respiratory movements, growth and decay of the brain and spinal cord—would be completely understood. Further, those phenomena which are always, and hence necessarily, simultaneous with mental phenomena, would also be perfectly understood. And it certainly were a great triumph of human knowledge if we were able to say that, on occasion of a given mental phenomenon, a certain definite motion of definite atoms would occur in certain definite ganglia and nerves. It would be profoundly interesting if we could thus, with the mind's eye, note the play of the brain-mechanism, in working out a problem in arithmetic, after the manner of a calculating-machine; or, even if we could say what play of the carbon, hydrogen, nitrogen, oxygen, phosphorus, and other atoms, corresponds to the pleasure we experience on hearing musical sounds; what whirl of such atoms answers to the climax of sensual enjoyment; and what molecular storm to the raging pain we feel when the trigeminus nerve is misused. The intellectual enjoyment afforded by Fechner's preliminary studies in psychophysics, and by Donders's measurements of the duration of simpler mental operations, gives reason to expect that such direct insight into the material conditions of mental phenomena would be highly instructive.

Still, as regards mental operations themselves, it is clear that, even with astronomical knowledge of the mind-organ, they would be as unintelligible as they are now. Were we possessed of such knowledge,

they would still remain perfectly unintelligible. Astronomical knowledge of the brain—the highest grade of knowledge we can expect ever to have—discloses to us nothing but matter in motion. But we cannot, by means of any imaginable movement of material particles, bridge over the chasm between the conscious and the unconscious.

Motion can only produce motion, or be converted back into potential energy. Potential energy can only produce motion, maintain static equilibrium, or exert pressure or traction. The sum of energy, however, remains the same. Beyond this law nothing can go in the physical world, nor can any thing fall short of it; the mechanical cause passes completely into the mechanical effect. Hence the mental phenomena, which in the brain appear in company with material phenomena, are, so far as our understanding is concerned, void of sufficient basis. They lie beyond the law of causality, and hence are unintelligible, like a *mobile perpetuum*. But they are also unintelligible on other grounds.

True, on superficial observation, it looks as though certain mental operations and conditions might be intelligible to us, from a knowledge of the material phenomena of the brain. Among such mental phenomena I might reckon memory, association of ideas, habit, specific talents, etc. It needs but little reflection to show that this is an error. We should only be acquainted with certain inner conditions of the soul's life, which are of about equal import with the external conditions created by sense-impressions; but we should know nothing about the origin of mental life in virtue of these conditions.

What conceivable connection subsists between definite movements of definite atoms in my brain, on the one hand, and on the other hand such (for me) primordial, indefinable, undeniable facts as these: "I feel pain, or pleasure; I experience a sweet taste, or smell a rose, or hear an organ, or see something red," and the immediately-consequent certainty, "Therefore I exist?" It is absolutely and forever inconceivable that a number of carbon, hydrogen, nitrogen, oxygen, etc., atoms should not be indifferent as to their own position and motion, past, present, or future. It is utterly inconceivable how consciousness should result from their joint action. If their respective positions and their motion were not indifferent to them, they would have to be regarded as each possessed of a consciousness of its own, and as so many monads. But this would not explain consciousness in general, nor would it in the least assist us in understanding the unitary consciousness of the individual.

That it is and ever will remain utterly impossible to understand higher mental operations from the mechanics of the cerebral atoms (supposing them to be known), needs not to be proved. Yet, as has been already remarked, we need not consider the higher forms of mental activity, in order to add weight to our argument. But its force is intensified by contrasting the absolute ignorance wherein astronomical

knowledge of the brain leaves us with regard to the origin of the lowest mental phenomena, and the complete solution of the highest problems of the physical world which we get from such knowledge. A brain that should, from one cause or another, be unconscious—for instance, one that should sleep without dreaming—would, had we astronomical knowledge of it, hold no secret; and, if we possessed astronomical knowledge of the rest of the body also, then the whole human machine, with its respiration, its heart-beats, its exchanges of materials, its heat, etc.—in short, every thing short of the essence of matter and force, would be fully deciphered. The dreamless sleeper is comprehensible to us, like the universe previous to consciousness. But, as, on the first awakening of consciousness, the world became doubly incomprehensible, so too is it with the sleeper, at the first appearance of a faint image in dreaming.

The irreconcilable conflict of the mechanical view of the universe with freedom of will, and hence indirectly with ethics, is no doubt a matter of high importance. The ingenuity of thinkers in all times has been exhausted in trying to reconcile them, and this question will afford exercise to the mind of man forever. To say nothing of the fact that free-will may be denied, whereas pleasure and pain are unquestionable; *desire*, which gives the impetus to exertion, and hence gives occasion to act, or not to act, is necessarily preceded by sense-impressions. Hence it is to the problem of sensation, and not, as I have once said, to that of free-will, that analytical mechanics leads.

And here is the other limit of our knowledge of Nature. It is no less absolute than the first limit. For two thousand years, despite all the advances made by natural science, mankind has made no substantial progress toward the understanding of matter and force, any more than toward the understanding of mental activity from its material conditions. And so will it ever be. Even the Mind imagined by Laplace, with its universal formula, would, in its efforts to overstep these limits, be like an aëronaut essaying to reach the moon. In its world of mobile atoms, the cerebral atoms are in motion indeed, but it is a dumb show. This Mind views their hosts, and sees them crossing each other's course, but does not understand their pantomime; they think not for him, and hence, as we have already seen, the world of this Mind is still meaningless.

In this Mind we have the measure of our own capacity, or rather our impotence. Our knowledge of Nature is thus shut up between two limits, the one forevermore determining our incapacity to comprehend matter and force, the other determining our inability to understand mental facts from their material conditions. Between these limits the man of science is lord and master; he dismembers and builds up, and no one durst say wherein his knowledge and his power are circumscribed. Beyond these limits he cannot now, nor can he ever, go.

But the more frankly the student of natural science acknowledges these appointed limits, and the more humbly he is reconciled to this ignorance, the more profoundly conscious is he of his right inductively to fashion his own views as to the relations between mind and matter, with perfect freedom, and untrammeled by myths, dogmas, or time-honored philosophies.

He sees material conditions in a thousand ways influencing mental life. To his unprejudiced mind there seems no reason to doubt that sense-impressions are really communicated to the so-called Soul. He sees the human mind grow with the brain as it were, and, according to the empiricists, he finds that the actual forms of his thought are constituted by means of external perceptions. In sleep, and in dreams, in fainting, in intoxication and narcosis, in the delirium of fever and in inanition, in mania, epilepsy, idiocy, microcephaly—in a thousand morbid states he sees the soul to be dependent on the constant or transient condition of the brain. No theological prejudice prevents him, as it did Descartes, from recognizing in the souls of animals the relatives of the human soul, and less perfect members of the same series of development. On the contrary, he sees that in the vertebrates those parts of the brain which physiological research and pathological experience prove to be the seat of the higher mental activities keep pace, in their comparative development, with the growth of these activities. Where mental capacity makes the immense leap from the anthropoid apes to man which is indicated by the power of speech, we find a corresponding leap in cerebral mass. The varied arrangement of similar elementary particles in the invertebrates instructs the investigator of Nature that here, as in other organs, there is question less of the general architecture than of the structural elements.

With awe and wonder he regards the microscopic molecule of nervous substance which is the seat of the laborious, constructive, orderly, loyal, dauntless soul of the ant. Finally, the development theory, coupled with the doctrine of natural selection, forces upon him the theory that the soul came into being as the result, gradually attained, of certain material combinations, and that probably, like other heritable endowments that are of use to the individual in the struggle for life, it has risen and perfected itself up to its present state through a countless series of generations.

Now, if the ancient thinkers found every interaction between body and soul unintelligible and impossible on their theories, and if their undoubted simultaneous coöperation is to be explained only by a Pre-established Harmony of the two substances, then the notion they formed of the soul, in conformity with their scholastic conceptions, must have been erroneous. The necessity of a scholastic conclusion so plainly in conflict with the reality, is, as it were, an apogogical demonstration of the falsity of their premises. In his simile of the two watches, Leibnitz, as has been well observed by Fechner, over-

looked the fourth and simplest supposition, viz., that perhaps the watches, whose simultaneous action is to be accounted for, may be after all only one. Whether we shall ever understand mental phenomena from their material conditions is a very different question from that other, viz., whether these phenomena are the product of material conditions. The former question might be decided in the negative without in the least affecting the latter, to say nothing of negativing it.

In the passage we have already cited, Leibnitz asserts that a mind incomparably higher than the human mind, but yet finite, could, if it were possessed of senses and technical powers of like perfection, form a body capable of mimicking the actions of man. He does not say that a man could be formed, for in his view the automaton of flesh and bone, which he regards as soulless, even as Descartes regarded all animals, still lacks the mechanically-incomprehensible soul-monad. The difference between Leibnitz's point of view and our own becomes very evident here. Imagine all the atoms whereof Cæsar was made up at a given moment, say as he stood at the Rubicon, to be by mechanical power brought together, each in its own place, and possessed of its own velocity in its proper direction. In our view Cæsar would then be restored mentally as well as bodily. This artificial Cæsar would at the first instant have the same sensations, ambitions, imaginings, as his prototype on the Rubicon, and the same memories, the same inherited and acquired faculties, etc. Suppose several artificial figures of the same model to be simultaneously formed out of a like number of other carbon, hydrogen, etc., atoms. What would at the first moment be the difference between the new Cæsar and his duplicate, beyond the differences in the places where they were formed? But the mind imagined by Leibnitz, after fashioning the new Cæsar and his many Sosiæ, could never understand how the atoms he himself had disposed in order, and set into action with proper velocity, could give mental activity.

Take Carl Vogt's bold expression, which in 1850 introduced a sort of mental tournament: "All those capacities which we call mental activities are only functions of the brain; or, to use a rather homely expression, thought is to the brain what the bile is to the liver, or the urine to the kidneys." The unscientific world were shocked at the simile, considering it to be an indignity to compare thought with the secretion of the kidneys. Physiology knows no such æsthetic discriminations of rank. In the view of physiology the kidney secretion is a scientific object of just the same dignity as the investigation of the eye, or the heart, or any so-called "nobler" organ. Nor is Vogt's expression worthy of blame on the ground that it represents mental activity as being the result of material conditions in the brain. Its faultiness lies in this, that it leaves the impression on the mind that the soul's activity is in its own nature as intelligible from the

structure of the brain, as is the secretion from the structure of a gland.

Wherever the material conditions of mental activity in the shape of a nervous system are lacking, as is the case with plants, the scientist cannot admit the existence of soul-life; and here he but seldom finds his views controverted. But what answer is to be made him if he were to require, as the condition of his believing in a soul of the universe, that there should be shown to him somewhere in the world, bedded in neuroglia, and nourished with warm arterial blood under due pressure, a system of ganglia and nerves corresponding in extent to the mental power of such a soul?

Finally, the question arises whether the two limits of our knowledge of Nature are not perhaps identical, i. e., whether, supposing we understood the nature of matter and force, we should not also understand how the substance that underlies them could, under certain conditions, feel, desire, and think. Certainly this is the simplest hypothesis, and, according to well-known principles of scientific research, until it is disproved it must be preferred to that other hypothesis, which, as we have said, makes the universe doubly incomprehensible. But such is the nature of things that we cannot attain clearness of view with regard to this point, and it were idle to dwell upon it.

With regard to the enigma of the physical world the investigator of Nature has long been wont to utter his "*Ignoramus*" with manly resignation. As he looks back on the victorious career over which he has passed, he is upheld by the quiet consciousness that wherein he now is ignorant, he may at least under certain conditions be enlightened, and that he yet will know. Bnt as regards the enigma what matter and force are, and how they are to be conceived, he must resign himself once for all to the far more difficult confession—

"IGNORABIMUS!"

THE CROOKED COURSES OF LIGHT.

AN article in the April MONTHLY explained the formation of luminous images upon the principle that light moves in straight lines through any uniform transparent medium; but at the same time no agency in Nature illustrates in so many ways its capability of being turned from a direct course. It may be thrown back by surfaces either directly in its own path, or at all possible angles, and it may be warped out of its course in various degrees as it passes through bodies, although in all cases the change of direction is governed by inflexible laws. The throwing back of rays from surfaces is known as the *reflection* of light; the bending or the fracture of the ray as it traverses a body is called the *refraction* of light.

The principle of reflection is illustrated in Fig. 1, in which a beam of the sun's rays enters through the shutter of a dark room, strikes upon a polished plane surface, and is reflected across the room in an opposite direction. The entering beam, *A B*, is called the incident ray. The vertical line, *B D*, is termed the *normal*, and the beam *B C*,

FIG. 1.

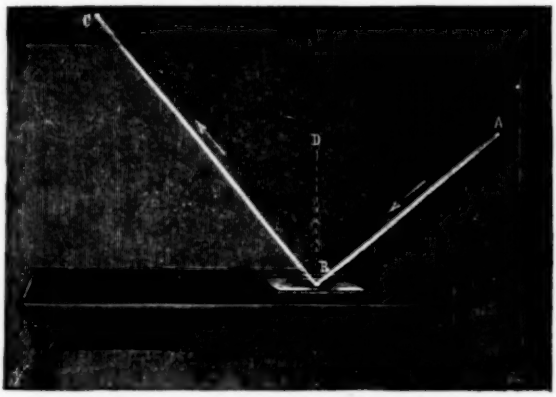


ILLUSTRATION OF THE REFLECTION OF LIGHT.

the reflected ray. The angle *A D B*, contained between the incident ray and the normal, is termed the angle of incidence; and the angle *C B D*, contained between the corresponding reflected ray and the normal, is called the angle of reflection. The reflection of light by polished surfaces, as in this case, is governed by two laws: 1. The incident ray, the normal, and the reflected ray, are always in the same plane; and, 2. The angle of incidence is always equal to the angle of reflection.

FIG. 2.

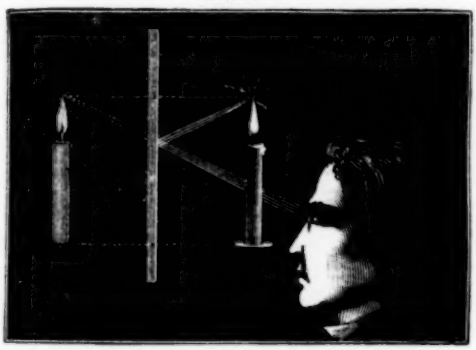
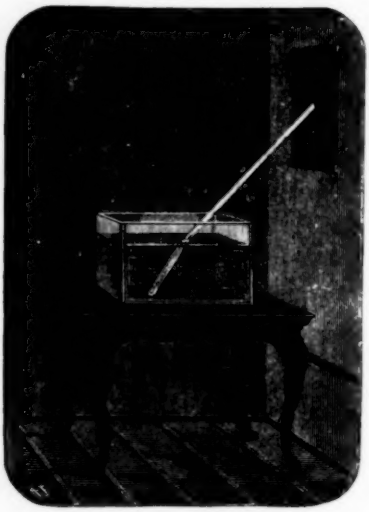


IMAGE OF A CANDLE IN A LOOKING-GLASS.

This is an example of what is known as *regular* reflection, but there is another kind of reflection in virtue of which bodies, when illu-

minated, throw back the light in all directions, and this is known as irregular reflection or diffusion. The effect of regular reflection, which depends upon the polish of surfaces, is not to make those surfaces visible, but to exhibit images of surrounding objects; it is by the light irregularly reflected upon their surfaces that objects are seen. In looking into a mirror, the image of the face is seen by regular reflection; the surface of the mirror is recognized by irregular reflection. "The mirrors of the ancients were of metal, usually of the compound now known as speculum-metal. Looking-glasses date from the twelfth century. They are plates of glass, coated at the back with an amalgam of quicksilver and tin, which forms the reflecting surface. This arrangement has the great advantage of excluding the air, and thus preventing oxidation. It is attended, however, with the disadvantage that the surface of the glass and the surface of the amalgam form two mirrors; and the superposition of the two sets of images produces a confusion which would be intolerable in delicate optical arrangements. The mirrors, or specula as they are called, of reflecting telescopes, are usually made of speculum-metal, which is a

FIG. 3.



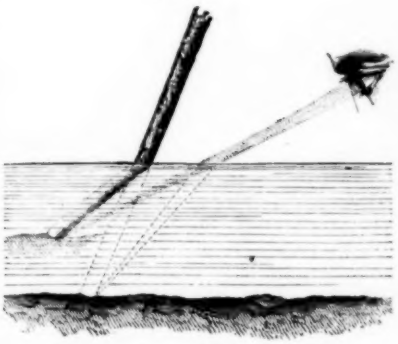
REFRACTION BY WATER.

bronze composed of about thirty-two parts of copper to fifteen of tin. Lead, antimony, and arsenic, are sometimes added. Of late years specula of glass coated in *front* with real silver have been extensively used; they are known as *silvered specula.* A coating of platinum has also been tried, but not with much success."

It is well known that the effect of plane mirrors or of any polished plane surface is to produce behind them images exactly similar both

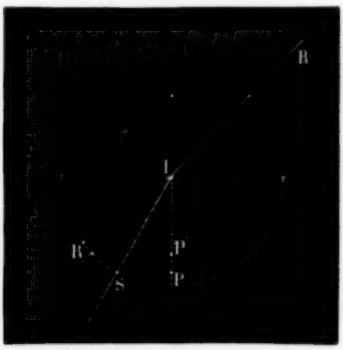
in form and size to the real objects in front of them. Fig. 2 represents the formation of an image of a candle in a common looking-glass. The reflection is shown as limited to the pencil of rays emitted by the highest point of the flame. The reflected rays which enter the eye are seen to be divergent like the incident rays, so that if they were produced backward they would meet at a point forming the image at the top of the flame. As all surfaces are made up of points, and each point of the object is reflected in the same manner, it is clear that the image formed by a plane mirror must symmetrically represent the object.

Fig. 4.



Appearance of a Stick in Water.

Fig. 5.



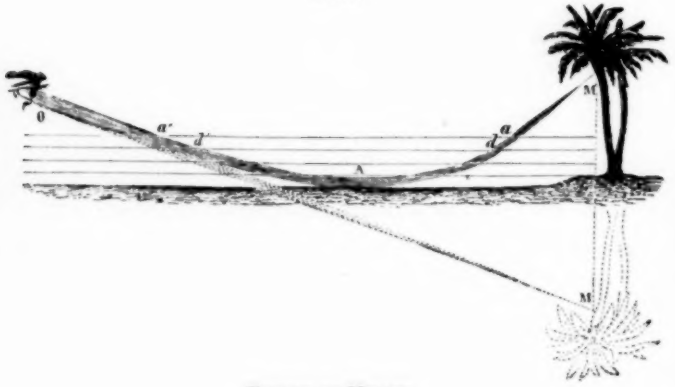
Snell's Law of Refraction.

But light-rays may be turned from their direct course in another way. When a beam passes obliquely from one transparent medium to another of different density, as from air to water or glass, its direction is changed and it is said to be refracted. This is illustrated in a very simple manner by Fig. 3, in which a ray of the sun, entering through an aperture in a dark room and received on the surface of water in a glass vessel, is seen to be broken as it were at the surface and bent downward.

A familiar experiment illustrating the same principle is to put a coin upon the bottom of an empty, opaque vessel, while the spectator places himself so that it is just hidden by the vessel's edge. If water be now poured into it, the bottom of the dish will appear to rise, and the coin will come in sight. The pencil of rays thus undergoes a sudden bend at the surface of the water, and reaches the eye by a crooked course, the effect of which is, that the spectator sees round or behind the obstacle. Fig. 4 shows how an inclined stick, partially immersed in water, presents a broken appearance. Transparent substances differ in this refracting power. Liquids exhibit it in a much higher degree than gases, and, as a general rule, the denser of two substances manifests the greater refracting effect. Hence it is common to speak of the change in the ray as it passes from a denser into a rarer medium, or the reverse.

Although a ray when passing from one medium to another is refracted at different angles depending upon its obliquity, yet the phenomenon is governed by one law and capable of being expressed in one formula. This is called the *index of refraction*, and was discovered by Willebrod Snell, a Dutch philosopher, about the year 1621. Fig. 5 will illustrate it. A circle is described around the point *I*, at which the ray *R* is incident upon the refracting surface. As the angle of the incident ray *R* varies with the normal, the angle of the refracted ray *S* will vary also. The law of refraction is, that the signs of these angles as *R' P*, *S P* will have a constant ratio. Each transparent substance has its index of refraction, and tables are given of these indices for different substances in the books upon physics.

FIG. 6.



THEORY OF MIRAGE.

In order that a ray may be refracted, it is by no means necessary that it should pass through bodies of widely different qualities, as from gases to liquids, or from liquids to solids; the effect may be seen in passing from one liquid to another of a different density, as where liquid bisulphide of carbon is covered with a layer of water floating upon its surface. The ray will then be seen to be bent on entering the water, and still more bent on passing from the water into the layer of bisulphide of carbon. In the same way rays of light passing through layers of the atmosphere of different density, undergo successive refractions. As the atmosphere varies in its density as we ascend from the earth, the rays of the sun and stars in passing through them are bent in their course, so that in point of fact we see them all through crooked and varying paths.

An appearance, as of water, is often seen in sandy deserts, where the soil is highly heated by the sun. The observer sees in the distance the reflection of the sky and of terrestrial objects, as on the surface of a lake. Fig. 6 illustrates how this effect may be produced. The air near the ground becomes so highly heated and rarefied that its

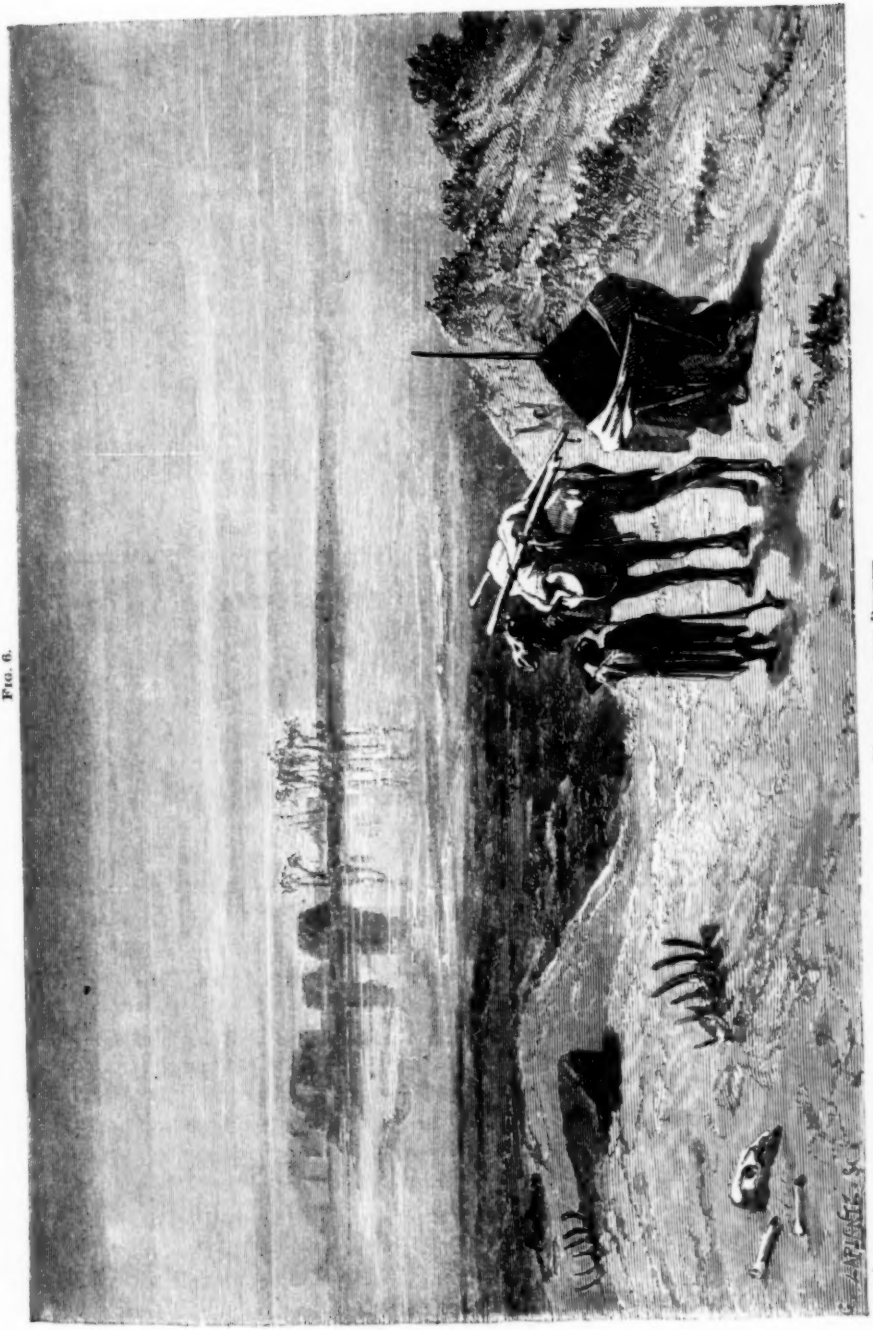


FIG. 6.

MIRAGE OF THE DESERT.

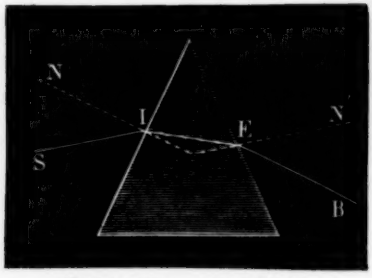
density within a certain distance *increases upward.* A ray, *M A*, Fig. 6, proceeding obliquely downward, will be rendered by refraction more and more nearly horizontal, until it is at length totally reflected, and it is then by successive refractions gradually elevated till it meets the eye of the observer at *O*, who thus sees an inverted image at *M*. Fig. 7 shows this effect as seen in the desert, where the eye is cheated by the appearance of water.

When a ray of light enters a piece of glass having parallel sides, as shown in Fig. 8, it is refracted, at the upper surface, downward, as in the case of water, and passes on straight until it reaches the lower surface. But, as it emerges, the reverse effect takes place, and the ray is refracted away from the perpendicular line. Its direction is now parallel to its original course, but it takes the path *S* instead of *S'*. The effect of this is, that whenever we look obliquely through plates of glass, as window-panes, all objects seen are slightly displaced, the degree of displacement varying of course with the thickness of the plate.

Fig. 8.

Vision through Glass Plate.

Fig. 9.



Refraction through Prism.

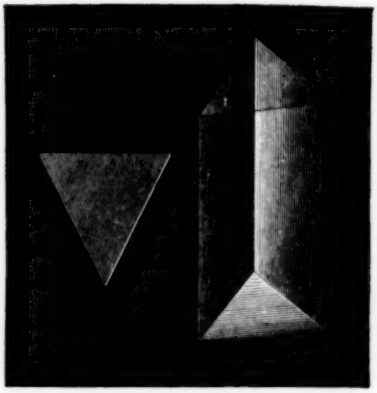
If, now, we take a piece of glass, of a wedge-shape, in which the sides are not parallel, a different effect is produced by the passage of the light through it. Such a piece of glass, or any transparent substance bounded by surfaces in this way, is called a *prism.* In Fig. 9, the ray *S* is represented as striking the prism at *I*, and, as it enters the glass, it is refracted toward the thicker part, and emerges at *E*. As it passes out into the air it is again bent in the same direction toward the base of the prism. The dotted lines, *N I* and *E N'* are drawn perpendicular to the faces of the prism, or at right angles, and serve to show that the path of the ray through the prism also makes equal angles with its surfaces.

The lines at which the faces of a prism meet are called its edge. Those in use are generally triangular, and very frequently equilateral, as shown in Fig. 10. For experiment, when used separately, they are commonly mounted upon stands, as shown in Fig. 11, which has several joints. The uppermost is for rotating the prism about its own

horizontal axis; the second is for tilting it at an angle with the horizon; the third is for turning it about a vertical axis; and the fourth for raising and lowering it through a range of several inches.

When a prism like that shown in Fig. 9 is interposed in the path of a narrow beam of sunlight, admitted into a dark room, its alteration

FIG. 10.



EQUILATERAL PRISM.

FIG. 11.

PRISM MOUNTED ON STAND.

of the direction of the ray is easily seen, and it will be found that the course of the light is altered, by refraction, some 40° or 50° from its original course.

The properties of light, to which we have here briefly referred, are interesting in themselves, and important to be known; but they have additional interest as preparing for an understanding of spectrum analysis, which will be taken up and popularly explained in future numbers of the MONTHLY.

SYNTHETIC CHEMISTRY.

BY PROF. JOHN W. LANGLEY,
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CHEMISTRY has been called *the* analytical science, and undoubtedly with justice in the past, since the most exact processes with which it deals are still those which go technically by the name of analysis; but, of recent years, the arts have been enriched by many perfumes, colors, and drugs, which are the results of careful and

laborious construction on the part of the manufacturer, operating under chemical laws. Gradually there has arisen a new branch of the science, whose aim is to produce artificially new compounds out of old material; and, since the living vegetable and animal offer familiar though mysterious examples of the same process, it is only natural that the philosopher should have tried to obtain, by known methods, some of those results which are so silently and wonderfully wrought out by the substance of living tissue. It will be the object of this paper to indicate, in a non-technical way, some of the steps which have been taken in the effort to compete with vitality.

The word *synthesis*, in its broad or general acceptance, signifies the union of any two or more substances to form a physically-homogeneous mass, and into a product which cannot be mechanically divided into dissimilar parts. Under this definition nearly every operation of chemistry would be synthetical; for, even in the case where an element is isolated, this is done only at the expense of some other bodies which pass into the condition of compounds; thus, when gold is precipitated in a metallic state from solution, we must use iron, zinc, or some other substance, which shall become oxidized and dissolved in the place of the precipitated gold.

Most cases of synthesis take place with great facility, automatically in fact, for, when coal is burned, we start the fire, and after that the oxygen and carbon unite to form carbonic acid, without any further effort on our part.

Now, in the world there are vast numbers of distinct compounds, some of which have a simple and others a complex structure; it is found, by long experience, that there is a general disposition on the part of these substances to pass from the state of feebly-united units to that of great fixity; thus, wood, which is composed of carbon, oxygen, and hydrogen principally, burns in the air into two stable and incombustible bodies, carbonic acid and water; and, in so doing, evolves a large amount of heat. Neither of these final products, so formed, can in any way be caused to evolve a further amount of energy, without bringing in the aid of external matter; dynamically, they are dead, as physiologically an animal is, when no longer capable of movement.

To raise a body into a state so that it contains within itself force in a potential form, and so as to be able to liberate this force spontaneously, when certain conditions are fulfilled, is an operation opposed to the general tendencies of the material world, and directly contrary to what may be called the habits of non-vitalized matter. Now, it is precisely this thing, this act of elevating some limited portion of matter to a higher plane, where its potentiality and complexity are both increased, that is meant by chemical synthesis, and it will be seen how much this use of the term restricts the meaning of the words as ordinarily used.

To raise a weight from the ground, to make water run up-hill, or to generate heat by friction, are all processes which require the expenditure of effort and material substance, if we would perform them ourselves. So in Nature, *this* form of synthesis is never accomplished without the expenditure of energy from some source. In the vegetable, the power comes directly from the sun, and the world in summer is colder and less brilliant (by an infinitesimal amount, it is true), because of that growth of leaves and wood which in the winter we reconvert into heat and light in our stoves; the animal gets the force for its synthesis by eating and consuming the products of vegetable life; and the chemist in his laboratory obtains his power mainly by converting a large amount of some complex body into simpler ones, in order to raise a smaller portion of some other mass to a more loosely aggregated and heterogeneous condition.

Starting with the elements and simple mineral bodies, the construction of such substances as salts, by the union of an acid and a base; of a suffocating gas, by the combustion of sulphur; of the conversion of iron into rust, by the action of water, air, etc., is very easy up to a certain point—so easy, that probably the very earliest beginnings of chemistry lay in observations of these facts. Certainly, the historic origin of the science in alchemy leaves no doubt of it as regards the middle ages, and, at the present day, most of the technical applications of the science are examples of the building up of compounds. So long as the experimenter's efforts were confined to mineral matter, he met with but little trouble; but, the moment he tried to reproduce any organic body, any compound which was the direct product of life, either animal or vegetable, he met a barrier which seemed to be insurmountable, and which bade fair never to be crossed. It was easy enough to analyze any of these vital products, and to determine the exact number and amount of their ingredients; but, once separated, the chemist vainly endeavored to make the elements reunite as they were before.

This was the state of things up to forty or fifty years ago. The power of the chemist had grown to be very great; he could either bind or loose, as pleased him, and he thought he had a tolerably complete knowledge of the elements and forces he was dealing with. Is it so much wonder, then, that he fell back on the assumption of the existence of a mysterious force outside of his domain, and that his defeat, coupled with the known impossibility of restoring life to the dead animal, should have led to the assumption that these organic bodies were the result of chemical processes which had been aided and controlled by a special entity, denominated vital force?

It is not the object of this paper to take sides on a question which is still a matter of debate; and, in regard to vital force, it has only to chronicle here some of the steps by which bodies, hitherto solely evolved by the action of living matter, may now, under the guidance

of the human intellect, and by the instrumentality of physical forces, be formed artificially at will.

In 1828, Wöhler, a German chemist, discovered that cyanate of ammonia, a purely mineral compound, under certain circumstances became changed into urea, without either loss or gain of any foreign body, the elements rearranging themselves to form a more complex structure. But here it was claimed, by the vitalists, that urea, being an excrementitious substance, and one of the waste products of the animal system, must be considered as in reality a mineral, and only accidentally, as it were, akin to animal tissue.

There exists in the bodies of ants a secretion which apparently serves them as a weapon; it is called formic acid, and, for some years after its discovery, was universally prepared by pounding up sundry ounces of ants in a mortar, and distilling them with water, when the bodies of the insects were left in the retort, and a diluted acid was found in the receiver. Analysis showed this substance to be formed of but three elements, and which, moreover, did not appear to be united in a complex manner. From certain analogies it was inferred that the acid might be obtained by some method of gradual oxidation; at last, the right substance was found, and, by duly acting on starch by oxygen, formic acid was produced. This was considered a very great step in advance, for an animal product had been at last formed from a vegetable one; and though it is true the body in question had a simpler constitution than the starch, still the plane of possible chemical processes had been elevated into the animal kingdom.

Quite recently a method has been discovered by which formic acid may be generated directly from its elements. To do this, carbon, say a bit of charcoal or coke, is heated in a limited supply of air, and the result is carbonic oxide; this gas, if exposed for a long time over caustic potash, combines with it, and this product, if distilled with oil of vitriol, yields formic acid. Thus the body has been formed without any thing having been used which is the product of life.

From this point progress was rapid, though at first apparently it rather tended away from the matter at issue. Previous study in the department of mineral chemistry had gradually forced the conception that the *position* of the elements in a compound had as much to do with its properties as did their number and amount, and it also had developed the fact that certain elements might be withdrawn and their places filled by something else, without changing the general character of the substance. Indeed, a compound body was called a chemical structure, and likened to a real edifice, in which the elementary atoms were the bricks of the house, and the resulting properties constituted the shape of the building. Now, by replacing one element by another, the same kind of change was produced as would be caused by the substitution of marble for bricks, or iron for stone, in the real house. Its appearance and habitability might be greatly altered, but its general shape and character remained.

As an example of this class of syntheses, the alcohols may be cited. Ordinary or wine alcohol is one of a large class of bodies which have similar features, and to which the same general name has been given; they constitute a series: thus, we have methylic alcohol, vinic alcohol, tetrylic alcohol, and so on. Now, in most of these we can substitute certain metals for hydrogen; for instance, metallic zinc can be thus inserted, and hydrogen removed, yielding zinc-ethyl, and, with the addition of oxygen, zinc-alcohol, and we get a colorless, fragrant liquid, in which, singularly enough, the zinc has so far lost its usual characteristics as to be both invisible and volatile. By carrying on the steps of this process still further, several metals may be introduced leading to the production of bodies of great resultant complexity, but which, through all their metamorphoses, are yet true members of the alcohol family.

In this sense the artificial processes may be said to surpass the natural ones; for man is able to add many individuals to a series of which Nature presents us with only scattered terms; and, in addition, in this particular group, he is able to form some of the natural members, such as wine alcohol and glycerine, by a direct process of construction, starting with the free elements, carbon, hydrogen, and oxygen. The method is briefly as follows: Carbon, in the form of black-lead, and therefore strictly a mineral substance, is heated intensely between the poles of a galvanic battery; when it is brilliantly incandescent, hydrogen gas is made to pass over its surface, in a suitable apparatus, the sides of which are kept comparatively cool, and the result is the formation of an invisible but extremely irritating gas, known as acetylene. Now, if acetylene is brought into a solution of copper, it combines with it, forming a dark-red explosive compound, and, if we act upon this body by hydrogen, the copper will be expelled, and olefiant gas, a sweetish ethereal substance, is obtained; and, finally, by distilling this last with sulphuric acid, alcohol is one of the products. Thus, in the several steps leading to this result, only mineral matter and ordinary chemical forces have been employed.

It must not be inferred, from the above meagre examples, that the number of syntheses is equally limited. Already there have been formed several natural vegetable acids, many of the alcohol family, some of the sugars, a whole host of ureas, a multitude of bodies analogous to the vegetable alkaloids, as well as many of the natural flavoring and coloring agents; these last, indeed, on an extended commercial scale.

So far as the evidence of experience goes, there seems no limit to the possible production of organic bodies which possess a definite chemical structure, at least of those which have the power of crystallizing, for the number, even now beyond the powers of an ordinary memory, is constantly increasing in an accelerating ratio, and already, as has been referred to, in some instances exceeds the range of Nature herself.

But are we entitled from these facts to indulge in self-glorification, and to assert that ultimately the exact reproduction of all the tissues found in living organisms will be possible? Certainly not, so far as the chemist is concerned, for other methods than those which properly belong to his science must obviously be sought to give the specialized forms and functions of living substance. The gulf which separates the artificial processes of synthetic chemistry from those really employed by the plant or animal is a wide one, across which lies as yet no solid bridge of fact and theory. It is known that all vegetable matter is derived primarily from carbonic acid, water, and ammonia, under the influence of the sun's rays, but the method by which this is done is still a mystery; a mystery, though, which may be cleared away, for very recently most interesting experiments have been made on the chemical action of light. All we know about vegetable chemistry with certainty is, that, whatever are the processes occurring in living tissue, most of them, in their earlier stages, are radically different from those of art. In the laboratory, synthesis starts with the elements, and from them, by exceedingly wasteful means, builds laboriously, from platform to platform, up to the desired height. On the other hand, the smallest speck of green vegetable tissue, if living, elaborates its substance, not from elementary bodies, but from compound ones, and those too which are among the most stable and most highly-oxidized known; each new step, then, in the artificial method, tends to carry us away, rather than to approximate us to the natural agent.

To return to the metaphor of the house. The chemist starts from the ground, and completes the edifice by piling *up*, one by one, the elementary bricks, and binding them together by the natural cement of atomic attraction. The living organism begins its labors at the top, and chiefly from the three firmly-knit compounds, water, carbonic acid, and ammonia, builds, by infinite gradation, *down* to an elementary foundation; and, at this day, science is scarcely more able to tell how this is done, than can the mason inform us how to start a block of houses by commencing with the roof.

This distinction as to methods includes obviously a vast domain of facts, that which has been referred to as the region lying between the natural and artificial synthetic methods. It is a sort of debatable land, for, though it is yet unknown, there is not the slightest proof that we shall not cross it some day, and possibly soon; and already the space is inhabited by speculations and embryonic theories, those shadowy precursors of substantial knowledge.

But the limit where the chemist *must* stop is the dividing line where the naked individuality of a chemical compound becomes clothed by the definite outline of an organ, a cell, or a speck of vitalized protoplasm; as soon as form other than crystalline appears, the sharpness of atomic characteristics is merged in the idiosyncrasies of the cellular

unit, and the chemist unaided can trace the work no further. A new set of forces apparently comes into play, and whether we say this new agent is vital force, or prefer to hold fast to scientific accumulations of facts and methods of thought, and regard the new mystery as but the result of new or changed conditions, it is equally evident that the province of pure chemistry ceases, for this limit was long ago self-assigned by the science, and indeed exists in a latent form in all its definitions.

Doubtless, either biology, or some as yet unspecified portion of science, drawn from the provinces of chemistry, physiology, anatomy, and physics, will take hold of this problem and solve it; to a certain extent is doing so now, and thus far the little light which has been gained seems to indicate the unbroken operation of uniform law acting through the known physical forces. Perhaps under this heading common gun-cotton offers one of the most striking examples. The cotton-fibre is an elongated cell, it is of course both vegetable and a special functional organ, and is therefore outside of what was above spoken of as the limit of pure synthesis; nevertheless, by the simple operation of immersing it in strong nitric acid, the properties of the tissue are remarkably changed. It has become highly combustible and explosive, and also soluble in a mixture of alcohol and ether. Now, the chemical change has consisted in a bodily removal of hydrogen, and the insertion into its place of a heavy red compound gas, and yet the shape, color, and texture of the cotton-fibre are so little altered that none but an expert can perceive any external change. Moreover, by a reverse process, gun-cotton can be changed back again into the ordinary article. It is, then, possible to most profoundly alter the chemical structure and properties of one of these organic cells without visibly changing its individual shape.

On the other hand, when gun-cotton is dissolved in ether, it becomes collodion, and when this solution is evaporated the vegetable tissue is left, not in its original fibrous form, but as an amorphous film; so here we have the cellular characteristics utterly destroyed by an agent which is not regarded as exerting any *chemical* action at all; and, by analogy, we may infer that the specialized forms of organized bodies are not therefore the necessary results of their atomic structure only.

Another example of the same kind is the facility by which certain crystals may be made to take on either an amorphous or an apparently cellular form. It is only necessary to add gum, or some other mucilaginous material, to the water in which they have been dissolved, to have them appear, on solidifying in this anomalous way, all their beautiful sharp angles and edges lost in a formless mass or in rounded nodules, like many of the renal and vesical calculi.

But this paper has already reached the limit of facts, and has perhaps entered too far into the region of speculation. In the controversy now going on, as to the spontaneous generation of life, some of

the contestants have appealed triumphantly to the results of synthetic chemistry, as indicating clearly that the "arcana of life had been entered and the mysterious divinity, vital force, overthrown." Does it not rather appear that chemistry, as yet, had not cut the Gordian knot, but was rather compelled to look to other sets of forces than those known as chemical for the chief agencies concerned in this work?

UNIVERSITIES: ACTUAL AND IDEAL.[1]

By Professor T. H. HUXLEY, LL. D., F. R. S.

ELECTED, by the suffrages of your four nations, rector of the ancient university of which you are scholars, I take the earliest opportunity which has presented itself, since my restoration to health, of delivering the address which, by long custom, is expected of the holder of my office.

My first duty, in opening that address, is to offer you my most hearty thanks for the signal honor you have conferred upon me—an honor of which, as a man unconnected with you by personal or by national ties, devoid of political distinction, and a plebeian who stands by his order, I could not have dreamed. And it was the more surprising to me, as the five-and-twenty years which have passed over my head since I reached intellectual manhood have been largely spent in no half-hearted advocacy of doctrines which have not yet found favor in the eyes of academic respectability—so that, when the proposal to nominate me for your rector came, I was almost as much astonished as was Hal o' the Wynd, "who fought for his own hand," by the Black Douglas's proffer of knighthood. And I fear that my acceptance must be taken as evidence that, less wise than the Armorer of Perth, I have not yet done with soldiering.

In fact, if, for a moment, I imagined that your intention was simply, in the kindness of your hearts, to do me honor, and that the rector of your university, like that of some other universities, was one of those happy beings who sit in glory for three years, with nothing to do for it save the making of a speech, a conversation with my distinguished predecessor soon dispelled the dream. I found that, by the constitution of the University of Aberdeen, the incumbent of the rectorate is, if not a power, at any rate a potential energy; and that, whatever may be his chances of success or failure, it is his duty to convert that potential energy into a living force, directed toward such ends as may seem to him conducive to the welfare of the corporation of which he is the theoretical head.

[1] The Inaugural Address of the Lord Rector of the University of Aberdeen, February 27, 1874.

I need not tell you that your late lord rector took this view of his position, and acted upon it with the comprehensive, far-seeing insight into the actual condition and tendencies, not merely of his own, but of other countries, which is his honorable characteristic among statesmen. I have already done my best, and, as long as I hold my office, I shall continue to endeavor, to follow in the path which he trod; to do what in me lies to bring this university nearer to the ideal—alas! that I should be obliged to say ideal—of all universities; which, as I conceive, should be places in which thought is free from all fetters; and in which all sources of knowledge, and all aids to learning, should be accessible to all comers, without distinction of creed or country, riches or poverty.

Do not suppose, however, that I am sanguine enough to expect much to come of any poor efforts of mine. If your annals take any notice of my incumbency, I shall probably go down to posterity as the rector who was always beaten. But if they add, as I think they will, that my defeats became victories in the hands of my successors, I shall be well content.

The scenes are shifting in the great theatre of the world. The act which commenced with the Protestant Reformation is nearly played out, and a wider and a deeper change than that effected three centuries ago—a reformation, or rather a revolution of thought, the extremes of which are represented by the intellectual heirs of John of Leyden, and of Ignatius Loyola, rather than by those of Luther and of Leo—is waiting to come on, nay, visible behind the scenes to those who have good eyes. Men are beginning, once more, to awake to the fact that matters of belief and of speculation are of absolutely infinite practical importance, and are drawing off from that sunny country "where it is always afternoon"—the sleepy hollow of broad indifferentism—to range themselves under their natural banners. Change is in the air. It is whirling feather-heads into all sorts of eccentric orbits, and filling the steadiest with a sense of insecurity. It insists on reopening all questions and asking all institutions, however venerable, by what right they exist, and whether they are, or are not, in harmony with the real or supposed wants of mankind. And it is remarkable that these searching inquiries are not so much forced on institutions from without, as developed from within. Consummate scholars question the value of learning; priests contemn dogma; and women turn their back upon man's ideal of perfect womanhood, and seek satisfaction in apocalyptic visions of some, as yet unrealized, epicene reality.

If there be a type of stability in this world, one would be inclined to look for it in the old universities of England. But it has been my business, of late, to hear a good deal about what is going on in these famous corporations; and I have been filled with astonishment

by the evidences of internal fermentation which they exhibit. If Gibbon could revisit the ancient seat of learning of which he has written so cavalierly, assuredly he would no longer speak of "the monks of Oxford, sunk in prejudice and port." There, as elsewhere, port has gone out of fashion, and so has prejudice—at least that particular fine, old, crusted sort of prejudice to which the great historian alludes.

Indeed, things are moving so fast in Oxford and Cambridge, that, for my part, I rejoiced when the royal commission of which I am a member had finished and presented the report which related to these universities; for, we should have looked like mere plagiarists, if, in consequence of a little longer delay in issuing it, all the measures of reform we proposed had been anticipated by the spontaneous action of the universities themselves.

A month ago, I should have gone on to say that one might speedily expect changes of another kind in Oxford and Cambridge. A commission has been inquiring into the revenues of many wealthy societies, in more or less direct connection with the universities, resident in those towns. It is said that the commission has reported, and that, for the first time in recorded history, the nation, and perhaps the colleges themselves, will know what they are worth. And it was announced that a statesman, who, whatever his other merits or defects, has aims above the level of mere party fighting, and a clear vision into the most complex, practical problems, meant to deal with these revenues.

But, *Bos locutus est.* That mysterious independent variable of political calculation, public opinion—which some whisper is, in the present case, very much the same thing as publican's opinion—has willed otherwise. The Heads may return to their wonted slumbers—at any rate for a space.

Is the spirit of change, which is working thus vigorously in the south, likely to affect the northern universities, and, if so, to what extent? The violence of fermentation depends, not so much on the quantity of the yeast, as on the composition of the wort, and its richness in fermentible material; and, as a preliminary to the discussion of this question, I venture to call to your minds the essential and fundamental differences between the Scottish and the English type of university.

Do not charge me with any thing worse than official egotism, if I say that these differences appear to be largely symbolized by my own existence. There is no rector in a English university. Now, the organization of the members of a university into nations, with their elective rector, is the last relic of the primitive constitution of universities. The rectorate was the most important of all offices in that University of Paris upon the model of which the University of Aberdeen was fashioned, and which was certainly a great and flourishing institution in the twelfth century.

Enthusiasts for the antiquity of one of the two acknowledged parents of all universities, indeed, do not hesitate to trace the origin of the "Studium Parisiense" up to that wonderful King of the Franks and Lombards, Karl, surnamed the Great, whom we all called Charlemagne, and believed to be a Frenchman, until a learned historian, by beneficent iteration, taught us better. Karl is said not to have been much of a scholar himself, but he had the wisdom of which knowledge is only the servitor. And that wisdom enabled him to see that ignorance is one of the roots of all evil.

In the "Capitulary" which enjoins the foundation of monasterial and cathedral schools, he says: "Right action is better than knowledge: but in order to do what is right we must know what is right."[1] An irrefragable truth, I fancy. Acting upon it, the king took pretty full compulsory powers, and carried into effect a really considerable and effectual scheme of elementary education through the length and breadth of his dominions.

No doubt, the idolators out by the Elbe, in what is now part of Prussia, objected to the Frankish king's measures; no doubt, the priests, who had never hesitated about sacrificing all unbelievers in their fantastic deities and futile conjurations, were the loudest in chanting the virtues of toleration; no doubt, they denounced as a cruel persecutor the man who would not allow them, however sincere they might be, to go on spreading delusions which debased the intellect, as much as they deadened the moral sense and undermined the bonds of civil allegiance; no doubt, if they had lived in these times, they would have been able to show, with ease, that the king's proceedings were totally contrary to the best liberal principles. But it may be said, in justification of the Teutonic ruler, first, that he was born before those principles, and did not suspect that the best way of getting disorder into order was to let it alone; and, secondly, that his rough and questionable proceedings did, more or less, bring about the end he had in view. For, in a couple of centuries, the schools he sowed broadcast produced their crop of men thirsting for knowledge and craving for culture. Such men, gravitating toward Paris, as a light amid the darkness of evil days, from Germany, from Spain, from Britain, and from Scandinavia, came together by natural affinity. By degrees they banded themselves into a society, which, as its end was the knowledge of all things knowable, called itself a "*Studium Generale;*" and, when it had grown into a recognized corporation, acquired the name of "*Universitas Studii Generalis;*" which, mark you, means not a "Useful Knowledge Society," but a "Knowledge-of-things-in-general Society."

[1] "Quamvis enim melius sit bene facere quam nosse, prius tamen est nosse quam facere."—"Karoli Magni Regis Constitutio de Scholis per singula Episcopia et Monasteria instituendis," addressed to the Abbot of Fulda. Baluzius, "Capitularia Regum Francorum," tomus i., p. 202.

And thus the first "university," at any rate on this side of the Alps, came into being. Originally it had but one faculty, that of arts. Its aim was, to be a centre of knowledge and culture, not to be, in any sense, a technical school.

The scholars seemed to have studied grammar, logic, and rhetoric; arithmetic and geometry; astronomy; theology; and music. Thus, their work, however imperfect and faulty, judged by modern lights, it may have been, brought them face to face with all the leading aspects of the many-sided mind of man. For these studies did really contain, at any rate, in embryo—sometimes, it may be, in caricature—what we now call philosophy, mathematical and physical science, and art. And I doubt if the curriculum of any modern university shows so clear and generous a comprehension of what is meant by culture as this old *trivium* and *quadrivium* does.

The students who had passed through the university course, and had proved themselves competent to teach, became masters and teachers of their younger brethren. Whence the distinction of masters and regents, on the one hand, and scholars, on the other.

Rapid growth necessitated organization. The masters and scholars, of various tongues and countries, grouped themselves into four nations; and the nations, by their own votes at first, and subsequently by those of their procurators, or representatives, elected their supreme head and governor, the rector—at that time the sole representative of the university, and a very real power, who could defy provosts interfering from without, or could inflict even corporal punishment on disobedient members within the university.

Such was the primitive constitution of the University of Paris. It is in reference to this original state of things, that I have spoken of the rectorate, and all that appertains to it, as the sole relic of that constitution.

But this original organization did not last long. Society was not then, any more than it is now, patient of culture, as such. It says to every thing, "Be useful to me, or away with you." And, to the learned, the unlearned man said then, as he does now: "What is the use of all your learning, unless you can tell me what I want to know? I am here blindly groping about, and constantly damaging myself by collision with three mighty powers: the power of the invisible God, the power of my fellow-man, and the power of brute Nature. Let your learning be turned to the study of these powers, that I may know how I am to comport myself with regard to them." In answer to this demand, some of the masters of the faculty of arts devoted themselves to the study of theology, some to that of law, and some to that of medicine; and they became doctors—men learned in those technical, or, as we now call them, professional branches of knowledge. Like cleaving to like, the doctors formed schools, or faculties, of theology, law, and medicine, which sometimes assumed airs of superiority over

their parent, the faculty of arts, though the latter always asserted and maintained its fundamental supremacy.

The faculties arose, by process of natural differentiation, out of the primitive university. Other constituents, foreign to its nature, were speedily grafted upon it. One of these extraneous elements was forced into it by the Roman Church, which in those days asserted with effect, that which it now asserts, happily without any effect in these realms, its right of censorship and control over all teaching. The local habitation of the university lay partly in the lands attached to the monastery of St. Geneviève, partly in the diocese of the Bishop of Paris; and he who would teach must have the license of the abbot, or of the bishop, as the nearest representative of the pope, so to do; which license was granted by the chancellors of these ecclesiastics.

Thus, if I am what archæologists call a "survival" of the primitive head and ruler of the university, your chancellor stands in the same relation to the papacy—and, with all respect for his grace, I think I may say that we both look terribly shrunken when compared with our great originals.

Not so is it with a second foreign element, which silently dropped into the soil of universities like the grain of mustard-seed in the parable; and, like that grain, grew into a tree in whose branches a whole aviary of fowls took shelter. That element is the element of endowment. It differed from the preceding, in its original design to serve as a prop to the young plant, not to be a parasite upon it. The charitable and the humane, blessed with wealth, were very early penetrated by the misery of the poor student. And the wise saw that intellectual ability is not so common, or so unimportant a gift, that it should be allowed to run to waste upon mere handicrafts and chares. The man who was a blessing to his contemporaries, but who so often has been converted into a curse, by the blind adherence of his posterity to the letter, rather than to the spirit, of his wishes—I mean the "pious founder"—gave money and lands, that the student who was rich in brain and poor in all else might be taken from the plough or from the stithy, and enabled to devote himself to the higher service of mankind; and built colleges and halls in which he might be not only housed and fed, but taught.

The colleges were very generally placed in strict subordination to the university by their founders; but, in many cases, their endowment, consisting of land, has undergone an "unearned increment," which has given these societies a continually-increasing weight and importance as against the unendowed, or fixedly-endowed university. In Pharaoh's dream, the seven lean kine eat up the seven fat ones. In the reality of historical fact, the fat colleges have eaten up the lean universities.

Even here in Aberdeen, though the causes at work may have been somewhat different, the effects have been similar; and you see how

much more substantial an entity is the very reverend the principal, analogue, if not homologue, of the principals of King's College, than the rector, lineal representative of the ancient monarchs of the university, though, now, little more than a "king of shreds and patches."

Do not suppose that, in thus briefly tracing the process of university metamorphosis, I have had any intention of quarreling with its results. Practically, it seems to me that the broad changes effected in 1858 have given the Scottish universities a very liberal constitution, with as much real approximation to the primitive state of things as is at all desirable. If your fat kine have eaten the lean, they have not lain down to chew the cud ever since. The Scottish universities, like the English, have diverged widely enough from their primitive model; but I cannot help thinking that the northern form has remained more faithful to its original, not only in constitution, but, what is more to the purpose, in view of the cry for change, in the practical application of the endowments connected with it.

In Aberdeen, these endowments are numerous, but so small that, taken altogether, they are not equal to the revenue of a single third-rate English college. They are scholarships, not fellowships; aids to do work—not rewards for such work, as it lies within the reach of an ordinary, or even an extraordinary, young man to do. You do not think that passing a respectable examination is a fair equivalent for an income, such as many a gray-headed veteran or clergyman would envy; and which is larger than the endowment of many regius chairs. You do not care to make your university a school of manners for the rich; of sports for the athletic; or a hot-bed of high-fed, hypercritical refinement, more destructive to vigor and originality than are starvation and oppression. No; your little bursaries of ten and twenty (I believe even fifty) pounds a year, enable any boy who has shown ability—in the course of his education in those remarkable primary schools which have made Scotland the power she is—to obtain the highest culture the country can give him; and, when he is armed and equipped, his Spartan alma mater tells him that, so far, he has had his wages for his work, and that he may go and earn the rest.

When I think of the host of pleasant, moneyed, well-bred young gentlemen, who do a little learning and much boating by Cam and Isis, the vision is a pleasant one; and, as a patriot, I rejoice that the youth of the upper and richer classes of the nation receive a wholesome and a manly training, however small may be the modicum of knowledge they gather, in the intervals of this, their serious business. I admit, to the full, the social and political value of that training. But, when I proceed to consider that these young men may be said to represent the great bulk of what the colleges have to show for their enormous wealth, *plus*, at least, a hundred and fifty pounds a year apiece, which each undergraduate costs his parents or guardians, I

feel inclined to ask, whether the rate-in-aid of the education of the wealthy and professional classes, thus levied on the resources of the community, is not, after all, a little heavy? And, still further, I am tempted to inquire what has become of the indigent scholars, the sons of the masses of the people, whose daily labor just suffices to meet their daily wants, for whose benefit these rich foundations were largely if not mainly instituted? It seems as if Pharaoh's dream had been rigorously carried out, and that even the fat scholar has eaten the lean one. And, when I turn from this picture to the no less real vision of many a brave and frugal Scotch boy, spending his summer in hard manual labor, that he may have the privilege of wending his way in autumn to this university, with a bag of oatmeal, ten pounds in his pocket, and his own stout heart to depend upon through the northern winter; not bent on seeking

"The bubble reputation at the cannon's mouth,"

but determined to wring knowledge from the hard hands of penury; when I see him win through all such outward obstacles to positions of wide usefulness and well-earned fame—I cannot but think that, in essence, Aberdeen has departed but little from the primitive intention of the founders of universities, and that the spirit of reform has so much to do on the other side of the border, that it may be long before he has leisure to look this way.

As compared with other actual universities, then, Aberdeen may, perhaps, be well satisfied with itself. But, do not think me an impracticable dreamer, if I ask you not to rest and be thankful in this state of satisfaction; if I ask you to consider, awhile, how this actual good stands related to that ideal better toward which both men and institutions must progress, if they would not retrograde.

In an ideal university, as I conceive it, a man should be able to obtain instruction in all forms of knowledge, and discipline in the use of all the methods by which knowledge is obtained. In such a university, the force of living example should fire the student with a noble ambition to emulate the learning of learned men, and to follow in the footsteps of the explorers of new fields of knowledge. And the very air he breathes should be charged with that enthusiasm for truth, that fanaticism of veracity, which is a greater possession than much learning; a nobler gift than the power of increasing knowledge; by so much greater and nobler than these, as the moral nature of man is greater than the intellectual—for veracity is the heart of morality.

But the man who is all morality and intellect, although he may be good and even great, is, after all, only half a man. There is beauty in the moral world and in the intellectual world; but there is also a beauty which is neither moral nor intellectual — the beauty of the world of art. There are men who are devoid of the power of seeing it, as there are men who are born deaf and blind, and the loss of

those, as of these, is simply infinite. There are others in whom it is an overpowering passion; happy men, born with the productive, or, at lowest, the appreciative, genius of the artist. But, in the mass of mankind, the æsthetic faculty, like the reasoning power and the moral sense, needs to be roused, directed, and cultivated; and I know not why the development of that side of his nature, through which man has access to a perennial spring of ennobling pleasure, should be omitted from any comprehensive scheme of university education.

All universities recognize literature in the sense of the old rhetoric, which is art incarnate in words. Some, to their credit, recognize art in its narrower sense, to a certain extent, and confer degrees for proficiency in some of its branches. If there are doctors of music, why should there be no masters of painting, of sculpture, of architecture? I should like to see professors of the fine arts in every university; and instruction in some branch of their work made a part of the arts curriculum.

I just now expressed the opinion that, in our ideal university, a man should be able to obtain instruction in all forms of knowledge. Now, by "forms of knowledge" I mean the great classes of things knowable; of which the first, in logical, though not in natural, order is knowledge relating to the scope and limits of the mental faculties of man; a form of knowledge which, in its positive aspect, answers pretty much to logic and part of psychology, while, on its negative and critical side, it corresponds with metaphysics.

A second class comprehends all that knowledge which relates to man's welfare, so far as it is determined by his own acts, or what we call his conduct. It answers to moral and religious philosophy. Practically, it is the most directly valuable of all forms of knowledge, but, speculatively, it is limited and criticised by that which precedes and by that which follows it in my order of enumeration.

A third class embraces knowledge of the phenomena of the universe, as that which lies about the individual man; and of the rules which those phenomena are observed to follow in the order of their occurrence, which we term the laws of Nature.

This is what ought to be called natural science, or physiology, though those terms are hopelessly diverted from such a meaning; and it includes all exact knowledge of natural fact, whether mathematical, physical, biological, or social.

Kant has said that the ultimate object of all knowledge is to give replies to these three questions: What can I do? What ought I to do? What may I hope for? The forms of knowledge which I have enumerated should furnish such replies as are within human reach, to the first and second of these questions. While to the third, perhaps, the wisest answer is, "Do what you can to do what you ought, and leave hoping and fearing alone."

If this be a just and an exhaustive classification of the forms of

knowledge, no question as to their relative importance, or as to the superiority of one to the other, can be seriously raised.

On the face of the matter, it is absurd to ask whether it is more important to know the limits of one's powers; or the ends for which they ought to be exerted; or the conditions under which they must be exerted. One may as well inquire which of the terms of a rule-of-three sum one ought to know, in order to get a trustworthy result. Practical life is such a sum, in which your duty multiplied into your capacity, and divided by your circumstances, gives you the fourth term in the proportion, which is your deserts, with great accuracy. All agree, I take it, that men ought to have these three kinds of knowledge. The so-called "conflict of studies" turns upon the question of how they may best be obtained.

The founders of universities held the theory that the Scriptures and Aristotle taken together, the latter being limited by the former, contained all knowledge worth having, and that the business of philosophy was to interpret and coördinate these two. I imagine that in the twelfth century this was a very fair conclusion from known facts. Nowhere in the world, in those days, was there such an encyclopædia of knowledge of all three classes as is to be found in those writings. The scholastic philosophy is a wonderful monument of the patience and ingenuity with which the human mind toiled to build up a logically consistent theory of the universe, out of such materials. And that philosophy is by no means dead and buried, as many vainly suppose. On the contrary, numbers of men of no mean learning and accomplishment, and sometimes of rare power and subtilty of thought, hold by it as the best theory of things which has yet been stated. And, what is still more remarkable, men who speak the language of modern philosophy nevertheless think the thoughts of the schoolmen. "The voice is the voice of Jacob, but the hands are the hands of Esau." Every day I hear "Cause," "Law," "Force," "Vitality," spoken of as entities, by people who can enjoy Swift's joke about the meat-roasting quality of the smoke-jack, and comfort themselves with the reflection that they are not even as those benighted schoolmen.

Well, this great system had its day, and then it was sapped and mined by two influences. The first was, the study of classical literature, which familiarized men with methods of philosophizing; with conceptions of the highest good; with ideas of the order of Nature; with notions of literary and historical criticism; and, above all, with visions of art, of a kind which not only would not fit into the scholastic scheme, but showed them a pre-Christian, and indeed altogether un-Christian world, of such grandeur and beauty that they ceased to think of any other. They were as men who had kissed the fairy queen, and, wandering with her in the dim loveliness of the underworld, cared not to return to the familar ways of home and father-

land, though they lay, at arm's-length, overhead. Cardinals were more familiar with Virgil than with Isaiah; and popes labored, with great success, to repaganize Rome.

The second influence was the slow, but sure, growth of the physical sciences. It was discovered that some results of speculative thought, of immense practical and theoretical importance, can be verified by observation; and are always true, however severely they may be tested. Here, at any rate, was knowledge, to the certainty of which no authority could add, or take away, one jot or tittle, and to which the tradition of a thousand years was as insignificant as the hearsay of yesterday. To the scholastic system, the study of classical literature might be inconvenient and distracting, but it was possible to hope that it could be kept within bounds. Physical science, on the other hand, was an irreconcilable enemy, to be excluded at all hazards. The College of Cardinals has not distinguished itself in physics or physiology; and no pope has, as yet, set up public laboratories in the Vatican.

People do not always formulate the beliefs on which they act. The instinct of fear and dislike is quicker than the reasoning process; and I suspect that, taken in conjunction with some other causes, such instinctive aversion is at the bottom of the long exclusion of any serious discipline in the physical sciences from the general curriculum of universities; while, on the other hand, classical literature has been gradually made the backbone of the arts course.

I am ashamed to repeat here what I have said elsewhere, in season and out of season, respecting the value of science as knowledge and discipline. But the other day I met with some passages in the address to another Scottish university, of a great thinker, recently lost to us, which express so fully, and yet so tersely, the truth in this matter, that I am fain to quote them:

"To question all things—never to turn away from any difficulty; to accept no doctrine either from ourselves or from other people without a rigid scrutiny by negative criticism; letting no fallacy, or incoherence, or confusion of thought step by unperceived; above all, to insist upon having the meaning of a word clearly understood before using it, and the meaning of a proposition before assenting to it—these are the lessons we learn" from workers in science. "With all this vigorous management of the negative element, they inspire no skepticism about the reality of truth or indifference to its pursuit. The noblest enthusiasm, both for the search after truth and for applying it to its highest uses, pervades those writers. . . . In cultivating, therefore," science as an essential ingredient in education, "we are all the while laying an admirable foundation for ethical and philosophical culture."[1]

[1] Inaugural address delivered to the University of St. Andrews, February 1, 1867, by J. S. Mill, Rector of the University (pp. 32, 33).

The passages I have quoted were uttered by John Stuart Mill; but you cannot hear inverted commas, and it is therefore right that I should add, without delay, that I have taken the liberty of substituting "workers in science" for "ancient dialecticians," and "science as an essential ingredient in education" for "the ancient languages as our best literary education." Mill did, in fact, deliver a noble panegyric upon classical studies. I do not doubt its justice, nor presume to question its wisdom. But I venture to maintain that no wise or just judge, who has a knowledge of the facts, will hesitate to say that it applies with equal force to scientific training.

But it is only fair to the Scottish universities to point out that they have long understood the value of science as a branch of general education. I observe, with the greatest satisfaction, that candidates for the degree of Master of Arts in this university are required to have a knowledge, not only of mental and moral philosophy, and of mathematics and natural philosophy, but of natural history, in addition to the ordinary Latin and Greek course; and that a candidate may take honors in these subjects and in chemistry.

I do not know what the requirements of your examiners may be, but I sincerely trust they are not satisfied with a mere book-knowledge of these matters. For my own part, I would not raise a finger, if I could thereby introduce mere book-work in science into every arts curriculum in the country. Let those who want to study books devote themselves to literature, in which we have the perfection of books, both as to substance and as to form. If I may paraphrase Hobbes's well-known aphorism, I would say that "books are the money of literature, but only the counters of science," science (in the sense in which I now use the term) being the knowledge of fact, of which every verbal description is but an incomplete and symbolic expression. And be assured that no teaching of science is worth any thing, as a mental discipline, which is not based upon direct perception of the facts, and practical exercise of the observing and logical faculties upon them. Even in such a simple matter as the mere comprehension of form, ask the most practised and widely-informed anatomist what is the difference between his knowledge of a structure which he has read about and his knowledge of the same structure when he has seen it for himself, and he will tell you that the two things are not comparable — the difference is infinite. Thus I am very strongly inclined to agree with some learned school-masters who say that, in their experience, the teaching of science is all waste time. As they teach it, I have no doubt it is. But, to teach it otherwise, requires an amount of personal labor and a development of means and appliances, which must strike horror and dismay into a man accustomed to mere book-work, and who has been in the habit of teaching a class of fifty without much strain upon his energies. And this is one of the real difficulties in the way of the introduction of physical

science into the ordinary university course, to which I have alluded. It is a difficulty which will not be overcome, until years of patient study have organized scientific teaching as well as, or I hope better than, classical teaching has been organized hitherto.

A little while ago, I ventured to hint a doubt as to the perfection of some of the arrangements in the ancient universities of England; but, in their provision for giving instruction in science as such, and without direct reference to any of its practical applications, they have set a brilliant example. Within the last twenty years, Oxford alone has sunk more than a hundred and twenty thousand pounds in building and furnishing physical, chemical, and physiological laboratories, and a magnificent museum, arranged with an almost luxurious regard for the needs of the student. Cambridge, less rich, but aided by the munificence of her chancellor, is taking the same course; and, in a few years, it will be for no lack of the means and appliances of sound teaching, if the mass of English university men remain in their present state of barbarous ignorance of even the rudiments of scientific culture.

Yet another step needs to be made before science can be said to have taken its proper place in the universities. That is its recognition as a faculty, or branch of study demanding recognition and special organization, on account of its bearing on the wants of mankind. The faculties of theology, law, and medicine, are technical schools, intended to equip men, who have received general culture, with the special knowledge which is needed for the proper performance of the duties of clergymen, lawyers, and medical practitioners.

When the material well-being of the country depended upon rude pasture and agriculture, and still ruder mining; in the days when all the innumerable applications of the principles of physical science to practical purposes were non-existent even as dreams—days which men living may have heard their fathers speak of—what little physical science could be seen to bear directly upon human life lay within the province of medicine. Medicine was the foster-mother of chemistry, because it has to do with the preparation of drugs and the detection of poisons; of botany, because it enabled the physician to recognize medicinal herbs; of comparative anatomy and physiology, because the man who studied human anatomy and physiology for purely medical purposes was led to extend his studies to the rest of the animal world.

Within my recollection, the only way in which a student could obtain any thing like a training in physical science was, by attending the lectures of the professors of physical and natural science attached to the medical schools. But, in the course of the last thirty years, both foster-mother and child have grown so big, that they threaten not only to crush one another, but to press the very life out of the unhappy student who enters the nursery; to the great detriment of all three.

I speak in the presence of those who know practically what medical education is; for I may assume that a large proportion of my hearers are more or less advanced students of medicine. I appeal to the most industrious and conscientious among you, to those who are most deeply penetrated with a sense of the extremely serious responsibilities which attach to the calling of a medical practitioner, when I ask whether, out of the four years which you devote to your studies, you ought to spare even so much as an hour for any work which does not tend directly to fit you for your duties?

Consider what that work is. Its foundation is a sound and practical acquaintance with the structure of the human organism, and with the modes and conditions of its action in health. I say a sound and practical acquaintance, to guard against the supposition that my intention is to suggest that you ought all to be minute anatomists and accomplished physiologists. The devotion of your whole four years to anatomy and physiology alone would be totally insufficient to attain that end. What I mean is, the sort of practical, familiar, finger-end knowledge which a watchmaker has of a watch, and which you expect that craftsman, as an honest man, to have, when you intrust a watch, that goes badly, to him. It is a kind of knowledge which is to be acquired, not in the lecture-room, nor in the study, but in the dissecting-room and the laboratory. It is to be had, not by sharing your attention between these and sundry other subjects, but by concentrating your minds, week after week, and month after month, six or seven hours a day, upon all the complexities of organ and function, until each of the greater truths of anatomy and physiology has become an organic part of your minds—until you would know them if you were roused and questioned in the middle of the night, as a man knows the geography of his native place and the daily life of his home. That is the sort of knowledge which, once obtained, is a life-long possession. Other occupations may fill your minds—it may grow dim, and seem to be forgotten—but there it is, like the inscription on a battered and defaced coin, which comes out when you warm it.

If I had the power to remodel medical education, the first two years of the medical curriculum should be devoted to nothing but such thorough study of anatomy and physiology, with physiological chemistry and physics; the student should then pass a real, practical examination in these subjects; and, having gone through that ordeal satisfactorily, he should be troubled no more with them. His whole mind should then be given, with equal intentness, to therapeutics, in its broadest sense, to practical medicine and to surgery, with instruction in hygiene and in medical jurisprudence; and of these subjects only—surely there are enough of them—should he be required to show a knowledge in his final examination.

I cannot claim any special property in this theory of what the

medical curriculum should be, for I find that views, more or less closely approximating these, are held by all who have seriously considered the very grave and pressing question of medical reform; and have, indeed, been carried into practice, to some extent, by the most enlightened examining boards. I have heard but two kinds of objections to them. There is, first, the objection of vested interests, which I will not deal with here, because I want to make myself as pleasant as I can, and no discussions are so unpleasant as those which turn on such points. And there is, secondly, the much more respectable objection, which takes the general form of the reproach that, in thus limiting the curriculum, we are seeking to narrow it. We are told that the medical man ought to be a person of good education and general information, if his profession is to hold its own among other professions; that he ought to know botany, or else, if he goes abroad, he won't be able to tell poisonous fruits from edible ones; that he ought to know drugs, as a druggist knows them, or he won't be able to tell sham bark and senna from the real articles; that he ought to know zoology, because—well, I really have never been able to learn exactly why he is to be expected to know zoology. There is, indeed, a popular superstition, that doctors know all about things that are queer or nasty to the general mind, and may, therefore, be reasonably expected to know the "barbarous binomials" applicable to snakes, snails, and slugs; an amount of information with which the general mind is usually completely satisfied. And there is a scientific superstition that physiology is largely aided by comparative anatomy—a superstition which, like most, once had a grain of truth at bottom; but the grain has become homœopathic, since physiology took its modern experimental development, and became what it is now —the application of the principles of physics and chemistry to the elucidation of the phenomena of life.

I hold as strongly as any one can do, that the medical practitioner ought to be a person of education and good general culture; but I also hold by the old theory of a faculty, that a man should have his general culture before he devotes himself to the special studies of that faculty; and I venture to maintain that, if the general culture obtained in the faculty of arts were what it ought to be, the student would have quite as much knowledge of the fundamental principles of physics, of chemistry, and of biology, as he needs, before he commenced his special medical studies.

Moreover, I would urge that a thorough study of human physiology is, in itself, an education broader and more comprehensive than much that passes under that name. There is no side of the intellect which it does not call into play, no region of human knowledge into which either its roots, or its branches, do not extend; like the Atlantic between the Old and the New Worlds, its waves wash the shores of the two worlds of matter and of mind; its tributary streams flow

from both; through its waters, as yet unfurrowed by the keel of any Columbus, lies the road, if such there be, from the one to the other; far away from that Northwest passage of mere speculation, in which so many brave souls have been hopelessly frozen up.

But, whether I am right or wrong about all this, the patent fact of the limitation of time remains. As the song runs:

> "If a man could be sure
> That his life would endure
> For the space of a thousand long years—"

he might do a number of things not practicable under present conditions. Methuselah might, with much propriety, have taken half a century to get his doctor's degree; and might, very fairly, have been required to pass a practical examination upon the contents of the British Museum, before commencing practice as a promising young fellow of two hundred, or thereabouts. But you have four years to do your work in, and are turned loose, to save or slay, at two or three and twenty.

Now, I put it to you, whether you think that, when you come down to the realities of life—when you stand by the sick-bed, racking your brains for the principles which shall furnish you with the means of interpreting symptoms, and forming a rational theory of the condition of your patient—it will be satisfactory for you to find that those principles are not there, but that, to use the examination slang which is unfortunately too familiar to me, you can quite easily "give an account of the leading peculiarities of the *Marsupialia*," or "enumerate the chief characters of the *Compositæ*," or "state the class and order of the animal from which castoreum is obtained."

I really do not think that state of things will be satisfactory to you; I am very sure it will not be so to your patient. Indeed, I am so narrow-minded myself, that if I had to choose between two physicians—one who did not know whether a whale was a fish or not, and could not tell gentian from ginger, but did understand the applications of the institutes of medicine to his art; while the other, like Talleyrand's doctor, "knew every thing, even a little physic"—with all my love for breadth of culture, I should assuredly consult the former.

It is not pleasant to incur the suspicion of an inclination to injure or depreciate particular branches of knowledge. But the fact, that one of those which I should have no hesitation in excluding from the medical curriculum is that to which my own life has been specially devoted, should, at any rate, defend me from the suspicion of being urged to this course by any but the very gravest considerations of the public welfare.

And I should like, further, to call your attention to the important circumstance that, in thus proposing the exclusion of the study of such branches of knowledge as zoology and botany, from those com-

pulsory upon the medical student, I am not, for a moment, suggesting their exclusion from the university. I think that sound and practical instruction in the elementary facts and broad principles of biology should form part of the arts curriculum: and here, happily, my theory is in entire accordance with your practice. Moreover, as I have already said, I have no sort of doubt that, in view of the relation of physical science to the practical life of the present day, it has the same right as theology, law, and medicine, to a faculty of its own in which men shall be trained to be professional men of science. It may be doubted whether universities are the places for technical schools of engineering, or applied chemistry, or agriculture. But there can surely be little question, that instruction in the branches of science which lie at the foundation of these arts, of a far more advanced and special character than could, with any propriety, be included in the ordinary arts curriculum, ought to be obtainable by means of a duly-organized faculty of science in every university.

The establishment of such a faculty would have the additional advantage of providing, in some measure, for one of the greatest wants of our time and country. I mean the proper support and encouragement of original research.

The other day, an emphatic friend of mine committed himself to the opinion that, in England, it is better for a man's worldly prospects to be a drunkard, than to be smitten with the divine dipsomania of the original investigator. I am inclined to think he was not far wrong. And, be it observed, that the question is not, whether such a man shall be able to make as much out of his abilities as his brother, of like ability, who goes into law, or engineering, or commerce; it is not a question of "maintaining a due number of saddle-horses," as George Eliot somewhere puts it—it is a question of living or starving.

If a student of my own subject shows power and originality, I dare not advise him to adopt a scientific career; for, supposing he is able to maintain himself until he has attained distinction, I cannot give him the assurance that any amount of proficiency in the biological sciences will be convertible into, even the most modest, bread-and-cheese. And I believe that the case is as bad, or perhaps worse, with other branches of science. In this respect Britain, whose immense wealth and prosperity hang upon the thread of applied science, is far behind France, and infinitely behind Germany.

And the worst of it is, that it is very difficult to see one's way to any immediate remedy for this state of affairs which shall be free from a tendency to become worse than the disease.

Great schemes for the endowment of research have been proposed. It has been suggested that laboratories for all branches of physical science, provided with every apparatus needed by the investigator, shall be established by the state; and shall be accessible, under due conditions and regulations, to all properly-qualified persons. I see no

objection to the principle of such a proposal. If it be legitimate to spend great sums of money on public libraries and public collections of painting and sculpture, in aid of the man of letters, or the artist, or for the mere sake of affording pleasure to the general public, I apprehend that it cannot be illegitimate to do as much for the promotion of scientific investigation. To take the lowest ground, as a mere investment of money, the latter is likely to be much more immediately profitable. To my mind, the difficulty in the way of such schemes is not theoretical, but practical. Given the laboratories, how are the investigators to be maintained? What career is open to those who have been thus encouraged to leave bread-winning pursuits? If they are to be provided for by endowment, we come back to the college fellowship system, the results of which, for literature, have not been so brilliant that one would wish to see it extended to science; unless some much better securities, than at present exist, can be taken that it will foster real work. You know that, among the bees, it depends on the kind of cell in which the egg is deposited, and the quantity and quality of food which is supplied to the grub, whether it shall turn out a busy little worker or a big idle queen. And, in the human hive, the cells of the endowed larvæ are always tending to enlarge, and their food to improve, until we get queens, beautiful to behold, but which gather no honey and build no comb.

I do not say that these difficulties may not be overcome, but their gravity is not to be lightly estimated.

In the mean while, there is one step in the direction of the endowment of research which is free from such objections. It is possible to place the scientific inquirer in a position in which he shall have ample leisure and opportunity for original work, and yet shall give a fair and tangible equivalent for those privileges. The establishment of a faculty of science in every university, implies that of a corresponding number of professional chairs, the incumbents of which need not be so burdened with teaching as to deprive them of ample leisure for original work. I do not think that it is any impediment to an original investigator to have to devote a moderate portion of his time to lecturing, or superintending practical instruction. On the contrary, I think it may be, and often is, a benefit to be obliged to take a comprehensive survey of your subject; or to bring your results to a point, and give them, as it were, a tangible objective existence. The besetting sins of the investigator are two: the one is the desire to put aside a subject, the general bearings of which he has mastered himself, and pass on to something which has the attraction of novelty; and the other, the desire for too much perfection, which leads him to

> "Add and alter many times,
> Till all be ripe and rotten;"

to spend the energies which should be reserved for action, in whitening the decks and polishing the guns.

The necessity for producing results for the instruction of others, seems to me to be a more effectual check on these tendencies, than even the love of usefulness or the ambition for fame.

But supposing the professorial forces of our university to be duly organized, there remains an important question, relating to the teaching power, to be considered. Is the professorial system—the system, I mean, of teaching in the lecture-room alone, and leaving the student to find his own way when he is outside of the lecture-room—adequate to the wants of learners? In answering this question, I confine myself to my own province, and I venture to reply for physical science, assuredly and undoubtedly, No. As I have already intimated, practical work in the laboratory is absolutely indispensable, and that practical work must be guided and superintended by a sufficient staff of demonstrators, who are for science what tutors are for other branches of study. And there must be a good supply of such demonstrators. I doubt if the practical work of more than twenty students can be properly superintended by one demonstrator—if we take the working-day at six hours, that is, twenty minutes apiece—not a very large allowance of time for helping a dull man, for correcting an inaccurate one, or even for making an intelligent student clearly apprehend what he is about. And, no doubt, the supplying of a proper amount of this tutorial, practical teaching is a difficulty in the way of giving proper instruction in physical science in such universities as that of Aberdeen, which are devoid of endowments; and, unlike the English universities, have no moral claim on the funds of richly-endowed bodies to supply their wants.

Examination—thorough, searching examination—is an indispensable accompaniment of teaching; but I am almost inclined to commit myself to the very heterodox proposition that it is a necessary evil. I am a very old examiner, having, for some twenty years past, been occupied with examinations on a considerable scale, of all sorts and conditions of men, and women too—from the boys and girls of elementary schools, to the candidates for honors and fellowships in the universities. I will not say that, in this case, as in so many others, the adage that familiarity breeds contempt holds good; but my admiration for the existing system of examination, and its products, does not wax warmer as I see more of it. Examination, like fire, is a good servant, but a bad master; and there seems to me to be some danger of its becoming our master. I by no means stand alone in this opinion. Experienced friends of mine do not hesitate to say that students whose career they watch, appear to them to become deteriorated by the constant effort to pass this or that examination, just as we hear of men's brains becoming affected by the daily necessity of catching a train. They work to pass, not to know; and outraged Science takes her revenge. They do pass, and they don't know. I have passed sundry examinations in my time, not without credit, and I confess I am

ashamed to think how very little real knowledge underlay the torrent of stuff which I was able to pour out on paper. In fact, that which examination, as ordinarily conducted, tests, is simply a man's power of work under stimulus, and his capacity for rapidly and clearly producing that which, for the time, he has got into his mind. Now, these faculties are by no means to be despised. They are of great value in practical life, and are the making of many an advocate, and of many a so-called statesman. But, in the pursuit of truth, scientific or other, they count for very little, unless they are supplemented by that long-continued, patient "intending of the mind" as Newton phrased it, which makes very little show in examinations. I imagine that an examiner, who knows his students personally, must not unfrequently have found himself in the position of finding A's paper better than B's, though his own judgment tells him, quite clearly, that B is the man who has the larger share of genuine capacity.

Again, there is a fallacy about examiners. It is commonly supposed that any one who knows a subject is competent to teach it; and no one seems to doubt that any one who knows a subject is competent to examine in it. I believe both these opinions to be serious mistakes; the latter, perhaps, the more serious of the two. In the first place, I do not believe that any one who is not, or has not been a teacher, is really qualified to examine advanced students. And, in the second place, examination is an art, and a difficult one, which has to be learned like all other arts.

Beginners always set too difficult questions—partly because they are afraid of being suspected of ignorance if they set easy ones, and partly from not understanding their business. Suppose that you want to test the relative physical strength of a score of young men. You do not put a hundred-weight down before them, and tell each to swing it round. If you do, half of them won't be able to lift it at all, and only one or two will be able to perform the task. You must give them half a hundred-weight, and see how they manœuvre that, if you want to form any estimate of the muscular strength ef each. So, a practised examiner will seek for information respecting the mental vigor and training of candidates from the way in which they deal with questions easy enough to let reason, memory, and method, have free play.

No doubt, a great deal is to done by the careful selection of examiners, and by the copious introduction of practical work, to remove the evils inseparable from examination; but, under the best of circumstances, I believe that examination will remain but an imperfect test of knowledge, and a still more imperfect test of capacity, while it tells next to nothing about a man's power as an investigator.

There is much to be said in favor of restricting the highest degrees, in each faculty, to those who have shown evidence of such original power, by prosecuting a research under the eye of the professor in whose province it lies; or, at any rate, under conditions which shall

afford satisfactory proof that the work is theirs. The notion may sound revolutionary, but it is really very old—for, I take it, that it lies at the bottom of that presentation of a thesis by the candidate for a doctorate, which has now too often become little better than a matter of form.

Thus far, I have endeavored to lay before you, in a too brief and imperfect manner, my views respecting the teaching half—the *magistri* and *regentes*—of the university of the future. Now let me turn to the learning half—the *scholares*.

If the universities are to be the sanctuaries of the highest culture of the country—those who would enter that sanctuary must not come with unwashed hands. If the good seed is to yield its hundred-fold harvest, it must not be scattered amid the stones of ignorance, or the tares of undisciplined indolence and wantonness. On the contrary, the soil must have been carefully prepared, and the professor should find that the operations of clod-crushing, draining, and weeding, and even a good deal of planting, have been done by the school-master.

That is exactly what the professor does not find in any university in the three kingdoms that I can hear of—the reason of which state of things lies in the extremely faulty organization of the majority of secondary schools. Students come to the universities ill-prepared in classics and mathematics, not at all prepared in any thing else; and half their time is spent in learning that which they ought to have known when they came.

I sometimes hear it said that the Scottish universities differ from the English in being to a much greater extent places of comparatively elementary education for a younger class of students. But it would seem doubtful if any great difference of this kind really exists; for a high authority, himself head of an English college, has solemnly affirmed that "elementary teaching of youths under twenty is now the only function performed by the university;" and that colleges are "boarding-schools in which the elements of the learned languages are taught to youths."[1]

This is not the first time that I have quoted those remarkable assertions. I should like to engrave them in public view, for they have not been refuted; and I am convinced that, if their import is once clearly apprehended, they will play no mean part when the question of university reorganization, with a view to practical measures, comes on for discussion. You are not responsible for this anomalous state of affairs now; but, as you pass into active life, and acquire the political influence to which your education and your position should entitle you, you will become responsible for it, unless each in his

[1] "Suggestions for Academical Organization, with Especial Reference to Oxford." By the Rector of Lincoln.

sphere does his best to alter it, by insisting on the improvement of secondary schools.

Your present responsibility is of another, though not less serious, kind. Institutions do not make men, any more than organization makes life; and even the ideal university we have been dreaming about will be but a superior piece of mechanism, unless each student strive after the ideal of the scholar. And that ideal, it seems to me, has never been better embodied than by the great poet, who, though lapped in luxury, the favorite of a court, and the idol of his countrymen, remained, through all the length of his honored years, a scholar in art, in science, and in life:

"Wouldst shape a noble life? Then cast
No backward glances toward the past:
And though somewhat be lost and gone,
Yet do thou act as one new-born.
What each day needs, that shalt thou ask;
Each day will set its proper task.
Give others' work just share of praise;
Not of thine own the merits raise.
Beware no fellow-man thou hate:
And so in God's hands leave thy fate."

—*Contemporary Review.*

ACTION OF SUNLIGHT ON GLASS.

By E. S. DRONE.

IN a quiet street at the "West End" of Boston, there stands a house, the window-sills and roof of which, for more than ten years, have been covered with hundreds of pieces of glass, exposed to the full force of the sun's rays during the whole or greater portion of every day, only being protected by covers in the event of snow-storms. The results of these experiments, instituted to show a change produced in the color of glass by the actinic rays of the sun, have been discussed in this country and in Europe, but as yet the cause of this remarkable phenomenon has not been fully explained.

As early as 1825, Prof. Faraday noticed a change of color in glass containing oxide of manganese, due to the action of solar light, and it was thought that advantage might in some cases be taken of this action for the removal of color in glass. Prof. Faraday found that glass of a pale color, or even colorless at first, became pink by long exposure to solar rays, while portions of the same glass, not so exposed, were apparently unaltered. This effect he attributed to the solar light acting upon the manganese. In 1839 Splittgerber recorded the following interesting fact in Poggendorf's *Annalen*, published in

Berlin: "I would mention a curious fact, in which the sunbeams have, if I may say so, done something in the art of penmanship—not only on the surface, but by inscribing characters through the body of the glass; and though the matter is based upon causes well known by experience, yet there has probably never before been so striking an instance of their effect known. I am in possession of a plate of glass which was used as a window-pane for more than twenty years, and on which was an inscription in gold letters. This inscription was taken off by grinding the plate on both sides, and polishing it so as to have a new surface. When the glass had been polished, the inscription could again be clearly seen. The parts which had been under the letters remained white, while the remainder of the plate had assumed a violet tint, in consequence of the manganese it contained, a coloring which permeates the whole mass, as the grinding of the surface proved. The uncovered part of the plate, especially when laid upon a white background, shows the clearly-readable characters."

From the above, it will be seen that the power of the sun's rays to change the color of glass has been publicly announced for at least a half-century; but it does not appear that elaborate and systematic experiments upon this subject were instituted prior to those referred to in the opening sentence of this article. These were begun in 1863, by Mr. Thomas Gaffield, a window-glass merchant of Boston, who has made an enthusiastic study of many matters pertaining to glass, and whose collection of authorities on this and kindred subjects is probably not equaled by any private, and by very few public, collections in existence. These experiments now cover a period of eleven years, and embrace some eighty different kinds of glass, of English, French, German, Belgian, and American manufacture, including specimens of rough and polished plate, crown, and sheet window-glass; flint and crown optical glass; opal and ground glass; colored pot-metal (i. e., glass colored in the pot during the process of melting); flashed and stained glass of various colors; and glass-ware and glass in the rough metal. The experiments have been conducted with pieces of glass usually four by two inches, of which several hundred specimens have been exposed, showing the effect of sunlight in producing a change of color by exposure, from one day in summer to several years. The changes produced in the colorless glasses are from white to yellow, from greenish to yellowish green, from brownish yellow to purple, from greenish white to bluish white, and from bluish white to a darker blue.

Mr. Gaffield's plan of procedure has been to cut a number of pieces of the size mentioned above, from the same sheet of glass, the number depending upon the nature of the experiment to be made. Suppose that white plate-glass is to be tested by exposure from one to twelve months: fourteen pieces, precisely alike, are cut from the same plate; two are carefully put away in a neat box, from which the light

is excluded, and twelve are exposed to the sunlight. At the end of each month one of the exposed pieces is withdrawn from the light, carefully marked with a diamond to show the length of time exposed, and placed in the small dark box. At the end of the year, therefore, the collection embraces fourteen pieces—two of the original color, and twelve showing the effects of exposure from one to twelve months. Other collections may be made to show the daily, weekly, and yearly progress of the sun's rays in changing the color of the glass.

Mr. Gaffield found that, in the time required to produce a change, different specimens of glass presented widely different qualities, the change being much more easily effected in some than in others. In some specimens a marked change of color was observed in a few days; others, after resisting the powerful influence of the solar rays for years, were finally overcome, and made to assume a new color. Several kinds, in which no perceptible change took place in three months, were very sensibly affected by an exposure of a year. But in almost all the change took place.

"It is very interesting," says Mr. Gaffield, "to witness any one of these series of specimens, showing, as in one of white plate, a gradual change, commencing in a day or a few days in summer, from greenish or bluish white, to a yellowish white, or light yellow, a deep and deeper yellow, until it becomes a dark yellow or gold color; and, in some Belgian sheet specimens, a gradual change, commencing in a few weeks in summer, from brownish yellow to deeper yellow, yellowish pink, pink, dark pink, purple, and deep purple."

One interesting experiment was carried on for one year with nine different kinds of glasses, representing plate, crown, and cylinder glass, the manufacture of both hemispheres, and almost every shade and color of what are known as colorless glasses. The results were as follows:

KIND OF GLASS.	Color before Exposure.	Color after Exposure.
French white plate...	Bluish white	Yellowish.
German crystal plate.	Light green.	Bluish tinge.
English plate.....	" "	Yellowish green.
English crown.....	" "	Light purple.
Belgian sheet.....	Brownish yellow.	Deep "
English sheet.....	Dark green.	Brownish green.
American crystal sheet	Light bluish white.	Purplish white.
" " "	Lighter " "	Light yellowish green.
" ordinary...	Bluish green.	No change.

These colors appear from an observation of the glass edgewise, when is seen a body of color two or four inches in depth, whereas the usual thickness of the glass varies from one-fourteenth to one-quarter of an inch, and shows its color easily only when a white curtain or paper is placed behind it.

Among other experiments made by Mr. Gaffield, two may be noticed as of peculiar interest, and as suggesting a process of producing

very delicate designs and pictorial effects on glass. In the first, an inscription was made on a piece of Belgian sheet-glass, in part with gold and silver leaf, and in part with black and white paint. The gold and silver leaf were washed off, but the letters painted in black and white remained. After an exposure of nearly two years the surface of the glass was cleaned, when the clearly-marked words of the inscription appeared in the original color of the glass, while the surrounding portions were changed by the action of the sunlight to a purple color. By the second experiment the gradually-increasing effect of sunlight on glass may be shown by exposing to the solar rays a piece of easily-changed glass. Take a piece about twenty inches long by four wide, and at each end cover a strip about four by two inches with black paint. At the end of one month, two months, and at biennial periods thereafter, paint an additional similar strip in black, until the entire piece is painted. Then, upon removing the paint, there will appear a single piece of glass presenting the original color, and all the gradations of color and hue presented by exposure from one to thirty-six months.

In 1825 Faraday thought that only glass containing oxide of manganese was subject to this change of color. In 1867 M. Pelouze did not "believe that there exists in commerce a single species of glass that does not change its shade in the sunlight." The results of Mr. Gaffield's experiments have led him to "affirm that a longer or shorter exposure to the direct action of the sun's rays will probably change in some degree the color of all or nearly all kinds of window-glass," and that the phenomenon is not limited to glass containing oxide of manganese. It should be observed that Mr. Gaffield's statement is limited to the ordinary window-glass, although embracing many different kinds of that class.

Specimens of flint and of colored glass have also been subjected to the test, but, with one or two exceptions, without exhibiting a change of color. An experiment, continued for five years, with red, yellow, green, blue, and purple pot-metal, i. e., glass colored in the pot, produced no change in any case except the purple. Still, this does not prove that changes may not be effected by longer exposure. Subsequently, Mr. Gaffield experimented with pot-metals, not of the primary colors, but of the intermediate ones, which most nearly approach those produced in colorless glass by sunlight exposure. In every specimen of the brownish, yellowish, and rose or purple colors thus exposed, a change in color or shade was produced in a short time. A change was also observed in the colorless body of some of the specimens of flashed and stained glass.

As pot-metal colors of this class were used in the early-painted windows, it is pertinently asked whether these experiments may not throw some light upon the many interesting questions relating to the alleged superiority of the old cathedral-glass.

"The fact of coloration," says Mr. Gaffield, "or change of color or shade by sunlight being established, must we not transfer some of our praise for the old artists in glass to the wonderful pencil of the brightest luminary of the heavens, which, during the centuries, has noiselessly but unceasingly been at work, deepening and mellowing the colors of all the windows of the venerable cathedrals of the world? We do not see to-day the glass as it was when it came from the artist's studio or the glass-factory. The dust of ages has accumulated upon its surface, the corroding tooth of Time has eaten into it; but how often has the wonderful alchemy of the sunlight done more in penetrating beneath the surface, and changing the shade or color of the entire body of the glass!"

The cause of the interesting phenomena above stated has not yet been explained, although not a few theories have been advanced to account for it. The change in color has been variously attributed to the presence of oxide of iron, to arsenic, to sulphur, and to oxide of manganese, in the constituent materials of the glass. But the true solution remains yet to be given. That the effect is not due to heat, but solely to the actinic rays of the sun, is shown by the fact that no change of color is produced in the glass when exposed to heat; while, on the contrary, after the discoloration has been produced by solar light, the colors thus acquired disappear under the action of heat, and the glass assumes its normal color. This process may be repeated indefinitely, the change of color being produced by solar light, and the original color restored by heat. It has also been shown that the effect is not produced by air or moisture.

Prominent among other interesting facts shown by these experiments is the varying effect of sunlight during each season, and each month of the year. The comparative actinic power of the rays during each month is shown, at the end of the year, by the comparative depth of yellow or purple color produced. The actinic effect increases from January to July, and decreases after the latter month; the greatest effect is observed in the summer, and the least in winter; in the spring and autumn it is about equal, being midway between that of winter and summer.

The comparative power of different kinds of glass to transmit the actinic rays was also tested. Of the colored glasses it was found that blue transmitted the most, purple less, and red and orange the least; which shows the propriety of the preference given by photographers to blue glass for skylights, because it transmits the blue rays, which exert the most active power. Mr. Gaffield's observations have not been confined to the glasses exposed on his own roof and window-sills; but he has been earnest in collecting, from various sources, specimens of window-glass that have been exposed for greatly-varying periods. By observing the portion of the pane exposed and that protected by the sash and putty, a comparison is afforded between the original and

the acquired color of the glass. Among the gathered specimens was one of crown-glass, set in a church in Lexington, Mass., in 1794, from which the windows were removed in 1846, and afterward used as covers for hot-beds. The original color, ascertained by removing the putty from the edges, was a light green, and that produced by seventy-three years' exposure, a purple. Mr. Gaffield's efforts have also been directed toward examining the old cathedral-glass of Europe, where such observation is practicable. He still continues with great enthusiasm the experiments begun eleven years ago, and carefully records the results of his observations on a well-known phenomenon, "in the hopes that they may add some mite to the sum of human knowledge, and may stimulate and aid those who are better versed in scientific studies, to ascertain the causes and exact operations of this interesting power of the sun's rays to paint the products of art, as they do so beautifully and wonderfully the works of Nature on the mountain, in the forest and field."

MEASURES OF MENTAL CAPACITY.

By J. W. REDFIELD, M. D.

SCIENCE cannot look otherwise than favorably upon every attempt to determine the quantitative relations of mind and body; and much ingenuity has been expended in the effort to arrive at a geometrical expression of it. Aristotle, "the father of Natural History," as Prof. Agassiz calls him, speaks of an angle of the forehead to an horizontal line of the face as an indication of intelligence, and it is evident that the Greek sculptors designedly represented the superhuman attributes of the gods by an angle exceeding that of the highest human. It is not strange, therefore, that, when Camper restored the lost science and art of the measurement of psychological development, under the name of the Facial Angle, in 1784, the scientific world gave it a cordial welcome. But of course it could not be accepted as veritable scientific truth without running the gantlet of the severest criticism. Its most vulnerable point was a claim to be something more than a mere general rule, applicable to the designation of the rank of a species or of a race in the scale of intellectual and moral elevation. It claimed to be applicable to the distinction between nationalities, and even between individuals of the same class of society, both as to facial and as to mental characteristics. This was too much, and on this ground Blumenbach and others attempted to demolish it as a rule altogether, and by very many were supposed to have succeeded. Like other favorites, it had the misfortune to be made too much of, the consequence being that it came to be treated as of little worth. And yet nearly all comparative anatomists and physiologists make use of it as a

general measure of the position of a vertebrate species in the scale of cerebral and mental development. As a mere "general rule," to which, as is familiarly said, "there are always exceptions," it is certainly invulnerable, and is too valuable to be dispensed with. Hence, naturalists, while declaring it to be unreliable, have made a general application of it to the species of vertebrates, and to the races of mankind. Not only so—they have attempted to find out the definite grains of allowance in its application to particular cases, to discover the corresponding defects in the instrument, and to correct, improve, and perfect it. May it not be that the mistake is not so much in the facial angle as in the misunderstanding of its significance? If this can be shown, naturalists and ethnologists ought to make haste to receive the much-honored and much-abused facial angle into more hearty favor than ever.

But it will hardly do to proceed to this pleasant task before stopping to notice the proposition of the article entitled "The Facial Angle," in the March number of THE POPULAR SCIENCE MONTHLY, to replace Camper's facial angle by another and better. The writer repudiates the angle of the frontal line with the base-line of the face, and proposes to supersede it by an angle of the frontal line with the axis of the body. He says, what everybody will admit, that the frontal line of the face is on a line with the axis of the body or spinal column, in the lowest vertebrates, and that the two lines are parallel with each other in man. The absurdity of finding a facial angle, or any other angle, between two parallel lines, is evident at a glance. It might take two or three glances, but no more, to convince the ordinary mind that those two lines, with the cerebrum and cerebellum between them, cannot come in contact with each other, and can therefore form no angle between them, even in the lower animals. Disregarding the interposition of the brain, and extending the front line of the face and the axial line of the body, in imagination, until they meet, the intersected angle is not facial, and in the anthropoids it is so high in the air overhead as to be essentially visionary. Perhaps this is the reason why we have to look in vain at the only facial angles represented in the article referred to, Figs. 2 and 3, to find an illustration of the new facial angle proposed, concluding finally that they were intended to illustrate the old one. The truth is, supposing the brain to unite, instead of separate, the frontal line of the face and the axial line of the body, the bending of the continuous right line formed by them in the lowest vertebrate fishes into the two parallel lines in man, the one facio-abdominal and the other occipito-dorsal, is not by angles at all, but by curvatures, and the union of the parallels is by an arch over the head. The arc in each case is a greater or less part of a circle, according to the grade of intellectual and moral development. For example: In the typical man, the facial and dorsal lines, being parallel and perpendicular, are united at the top by a semicircle, very nearly

describing "the dome of thought, the temple of the soul." In the gorilla, the same lines, being inclined to each other, are united by about a quarter of a circle, nearly circumscribing the cranial and mental capacity of that venerable progenitor of ours. In the goat, the same lines, being still more inclined, are united by about an eighth of a circle, giving verge and room enough for his caprices. And so on to the least part of a circle, representing the least cerebral and mental capacity.

The rule of comparison here indicated will apply perfectly to each one of the ten profiles illustrating the scale of development in the principal figure of the article in question; but that artificial angle of the frontal line of the face to the dorsal line of the body will not apply at all to intelligent human beings, except in the case of the Flatheads, whose peculiar conformation has been produced by a too rigid application of it in their plastic infancy. In man as Nature made him, the front line of the facial angle can form an angular relation to the axis of the body *through the base-line* of the facial angle, and in no other way. At the top of the head the front and dorsal lines can only meet in a curve, and there they form what may more properly be called the cranial arch than the facial angle. The facial angle of Camper is truly an angle and truly facial, but the proposed substitute for it is neither. Nature really does form angles of varying acuteness and obtuseness to the base-line of the face at its two extremities—very acute angles between it and the front line of the face at its anterior extremity, and very obtuse angles between it and the line of the spinal column at its posterior extremity, in the lower vertebrates, and almost right angles at the same points in human beings. Those formed by the front and base lines of the face constitute the facial angle of the upper part of the face, and indicate the degrees of intellectual and artistic development: those formed by the base-line of the face and the axial line of the neck constitute the facial angle of the lower part of the face, and indicate the degrees of affectional and passional development.

To do full justice to the article we have stopped to consider, we must not slight the assertion on which the author bases his objection to Camper's facial angle and his preference for his own, namely, that "the base of the skull does not keep in harmony" with the front of the face in the changes that occur through the stages of vertebrate evolution, but that it "varies irregularly," while the "axis of the body" does not. A little examination will show this to be a great mistake. While the lines representing the front face and dorsal surfaces are "effecting a grand variation of 180°, or the half of a circle"—beginning with the lowest vertebrate, in which those lines are "in direct line" with each other, and ending with the highest vertebrate, in which they are parallel with each other—the line representing the base of the face, extending along the floor of the

nostril to the occipital condyle, remains stationary. While the upper jaw maintains its fixed position, the lower jaw plays upon it; and so, while the base-line of the face in the upper jaw remains steadfast, the lines based and dependent upon it—the front facial line above, and the axial line below—are each effecting variations of 90° in relation to it, the one in relation to its anterior extremity and upper surface, and the other in relation to its posterior extremity and under surface, passing on the way through the angles represented in *a b*, Fig. 1, and ending as represented in *a b*, Fig. 2—the two variations together con-

FIG. 1.

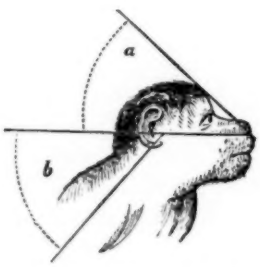
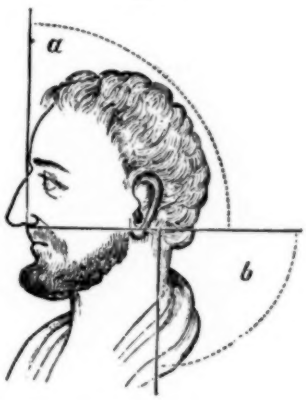


FIG. 2.



DEGREES OF THE SUPERIOR AND INFERIOR FACIAL ANGLES.

stituting the variation of 180°, or the half-orbit before mentioned. The base-line of the skull, so far from "varying irregularly," varies not at all, but is always straight, and in the most natural position of the head is always horizontal, while the frontal line of the face and the dorsal line of the body diverge more and more from the horizontal, and become more and more irregular in figure. The position of the head natural to social intercourse and to an outlook upon the horizon, as the general rule, is the one thing in which not only all men, but all vertebrate animals, are agreed, but they take infinite liberty to disagree in all other things, for the sake of showing the infinite diversity of individualities necessary to their harmonious interrelations and to the perfect individuality of the whole. When a man's "head is level," he is on a plane of equality, as a man and an animal, not only with his fellow-men, but with his fellow-creatures, and in a position to harmonize his differences with theirs. This horizontal position of the base-line of the face makes it the standard by which to compare the other lines, and by which to estimate the degrees of intelligence and affection as indicated by the degrees of the angles they make with it. When we consider how irregular in position and contour the spine and the features of the face become in the course of transition from the

lowest vertebrate forms to the highest, we see the absurdity of making either of these lines the basis of an angle in relation to the other. Take the novel rule, that for the true facial angle "the relation of the [front] face is not to the base of the skull, but to the axis of the body," and, for example, apply it to the camel! What sort of work would we make in deciphering such a hieroglyphical facial angle as that? But, considering the invariable straightness of the base of the skull, and its horizontal position in the attitude of attention, or in the social exercise of the external and internal senses and emotions, and considering at the same time the infinite variety of forms and motions given by these faculties to the features and muscles of the face and to the spinal column and its appendages, we see the propriety of making the base-line the standard of comparison for the two other lines in the construction of our facial angles and in our method of using them. All things considered, we may plant ourselves anew on the base-line of the old facial angle, assured that it is what its name signifies—fundamental, the centre of support and dependence between the transitional and variable lines, and presenting fixed extremities, constituting axial centres, in relation to which the movable lines are radii, forming with the base-line angles of all degrees between one and ninety in the development of animal life, from the lowest vertebrate form up to its highest and most perfect type. No one can read Camper's work "On the Connection between the Science of Anatomy and the Arts of Drawing, Painting, and Statuary," and examine its numerous and scrupulously accurate illustrations, without being convinced that the facial angle there described is founded in Nature, in spite of all the criticisms he or others may be able to pass upon it. If it be true, as Herbert Spencer says, that science is distinguished from common knowledge by being a more accurate system of measurements of ordinary phenomena, guided by more accurately understood and applied principles of generalization, Camper's facial angle may be regarded as the first step of a strictly scientific mind in the erection of a positive science of Comparative Physico-Psychology; and we have only to learn its true significance better than the master, by following the same induction of generals in regard to each particular line of it that he followed in regard to the whole, in order to complete the magnificent superstructure for which he laid so solid a foundation.

LAW AND INSANITY.[1]

By HENRY MAUDSLEY, M.D.

LOOKING back at the strange and erroneous notions which were formerly entertained of the nature and causes of insanity, and considering what little observation was made of its manifold varieties, we cannot wonder that its jurisprudence was in a very defective state. At first two kinds of insanity only seem to have been recognized by English law—*idiocy* and *lunacy:* the idiot who, from his nativity, by a perpetual infirmity is *non compos*, and the lunatic, who hath sometimes his understanding, and sometimes not, *aliquando gaudet lucidis intervallis*, and therefore is *non compos mentis*, so long as he hath not understanding. But as time went on a partial insanity was recognized as distinct from total insanity, although this partial insanity was declared not to absolve a person from responsibility for his criminal acts. "There is," says Lord Hale, "a partial insanity, and a total insanity. The former is either in respect to things, *quoad hoc vel illud insanire.* Some persons that have a competent use of reason in respect of some subjects, are yet under a particular *dementia* in respect of some particular discourses, subjects, or applications; or else it is partial in respect of degrees; and this is the condition of very many, especially melancholy persons, who for the most part discover their defect in excessive fears and griefs, and yet are not wholly destitute of the use of reason; and this partial insanity seems not to excuse them in the committing of any offense for its matter capital; for, doubtless, most persons that are felons of themselves and others are under a degree of partial insanity when they commit these offenses. It is very difficult to define the invisible line that divides perfect and partial insanity; but it must rest upon circumstances duly to be weighed by judge and jury, lest, on the one side, there be a kind of inhumanity toward the defects of human nature; or, on the other side, too great an indulgence given to great crimes." The invisible line which it was so difficult to define was not, let it be noted, between sanity and insanity, but between perfect and partial insanity. It was thought no inhumanity toward the defects of human nature to punish as a fully responsible agent a person who was suffering from partial insanity, whatever influence the disease might have had upon his unlawful act.

The principle thus laid down by Lord Hale was subsequently acted upon in English courts. Thus, in the trial of Arnold, an undoubted lunatic, for shooting at Lord Onslow, in 1723, Mr. Justice Tracy said: "It is not every kind of frantic humor, or something unaccountable in a man's actions, that points him out to be such a madman as is ex-

[1] From advance sheets of "Responsibility in Mental Disease," No. 9 of the "International Scientific Series."

empted from punishment: it must be a man that is totally deprived of his understanding and memory, and doth not know what he is doing, no more than an infant, than a brute or a wild beast; such a one is never the object of punishment." In this respect a wide distinction was maintained between civil and criminal cases; for while the law would not allow exemption from punishment for criminal acts unless the reason was entirely gone, it invalidated a person's civil acts, and deprived him of the management of himself and his affairs, when his insanity was only partial, and when the act voided had no discoverable relation to it. A man's intellect might not be sufficient to enable him to conduct his affairs, and to dispose of his property, though quite sufficient to make him responsible for a criminal act: it was right to hang for murder one who was not thought fit to take care of himself and his affairs.

It was at the trial of Hadfield, in 1800, for shooting at the king in Drury Lane Theatre, that Lord Hale's doctrine was first discredited, and a step forward made for the time. The attorney-general, who prosecuted, had appealed to this doctrine, and told the jury, in accordance with it, that, to exempt a person from punishment on the ground of insanity, there must be a total deprivation of memory and understanding. Mr. Erskine, who was counsel for the defense, argued forcibly in reply, that if such words were taken in their literal sense, "no such madness ever existed in the world;" that in all the cases that had filled Westminster Hall with complicated considerations, "the insane persons had not only had the most perfect knowledge and recollection of all the relations they stood in toward others, and of the acts and circumstances of their lives, but had in general been remarkable for subtlety and acuteness; and that delusion, of which the criminal act in question was the immediate unqualified offspring, was the kind of insanity which should rightly exempt from punishment. Delusion, therefore, where there is no frenzy or raving madness, is the true character of insanity." There was no doubt that Hadfield knew right from wrong, and that he was conscious of the nature of the act before he committed it; he manifested design in planning and cunning in executing it; he expected also that it would subject him to punishment, for this was his motive in committing it; still it was plain to everybody that he was mad, and that the act was the product of his madness. The result was that he was acquitted, the acquittal not having taken place in consequence of a judicial adoption of delusion in place of the old criterion of responsibility, as it has sometimes been said, but having been rather a triumph of Erskine's eloquence, and of common-sense over legal dogma.

In the next remarkable case, that of Bellingham, who was tried for the murder of Mr. Spencer Perceval, in 1812, a conviction took place, and the prisoner was executed, although it was perfectly clear that he had acted under the influence of insane delusions; the attorney-general,

who prosecuted, declaring, and Chief-Justice Mansfield, who tried the case, concurring, "upon the authority of the first sages in the country, and upon the authority of the established law in all times, which has never been questioned, that although a man might be incapable of conducting his own affairs, he may still be answerable for his criminal acts, if he possess a mind capable of distinguishing right from wrong." Note here, then, that a modification had now been made in the test of responsibility; in place of its being required that the sufferer, in order to be exempt from punishment, should be totally deprived of understanding and memory, and know not what he was doing, no more than a brute or a wild beast—in place, that is, of what might be called the "wild-beast" form of the knowledge-test, the power of distinguishing right from wrong was insisted on as the test of responsibility. The law had changed considerably without ever acknowledging that it had changed. Let it be observed, however, that it was the power of distinguishing right from wrong, not in relation to the particular act, but generally, which was made the criterion of responsibility in this case; for Lord Mansfield, speaking of the kind of insanity in which the patient has the delusion of being injured, and revenges himself by some hostile act, said that, "if such a person were capable, *in other respects*, of distinguishing right from wrong, there was no excuse for any act of atrocity which he might commit under this description of derangement. It must be proved beyond all doubt that, at the time he committed the atrocious act, he did not consider that murder was a crime against the laws of God and Nature."[1]

Thus far it is evident that principle was changing and practice was uncertain. After the old "wild-beast" form of the knowledge-test had been quietly abandoned, when the enunciation of it caused too violent a shock to the moral sense of mankind, we find two theories acted upon in practice: in the case of Hadfield the existence of delusion instigating the criminal act was the reason of his acquittal; in

[1] Dr. Ray thus comments upon this doctrine: "That the insane mind is not entirely deprived of this power of moral discernment, but on many subjects is perfectly rational and displays the exercise of a sound and well-balanced mind, is one of those facts now so well established, that to question it would only display the height of ignorance and presumption. The first result, therefore, to which the doctrine leads is, that no man can successfully plead insanity in defense of crime; because it can be said of no one who would have occasion for such a defense, that he was unable in any case to distinguish right from wrong. . . . The purest minds cannot express greater horror and loathing of various crimes than madmen often do, and from precisely the same causes. Their abstract conceptions of crime, not being perverted by the influence of disease, present its hideous outlines as they ever were in the healthiest condition; and the disapprobation they express at the sight arises from sincere and honest convictions. The *particular* criminal act, however, becomes divorced in their minds from its relations to crime in the *abstract;* and, being regarded only in connection with some favorite object which it may help to obtain, and which they see no reason to refrain from pursuing, is viewed, in fact, as of a highly-laudable and meritorious nature. Herein, then, consists their insanity—not in preferring vice to virtue, in applauding crime and deriding justice, but in being

Bellingham's case, an absence of knowledge of right and wrong generally, not in respect of the particular act, was deemed necessary to exempt the individual from punishment; the latter theory being entirely inconsistent with the former, and neither of them being consistently acted upon in subsequent trials. Most often a knowledge of right and wrong, without reference to the particular act, was plainly declared by the judge to be the simple and sufficient criterion of responsibility, and the jury was instructed accordingly; but this criterion was sometimes modified by the qualifications which judges introduced to meet their individual views, or to prevent the conviction of a person who was plainly insane and irresponsible. There was no settled principle, no actual uniformity of practice, no certainty of result.

In this uncertain way matters went on until a great sensation was made by the murder, in 1843, of Mr. Drummond by McNaughten, who shot him under the influence of a delusion that he was one of a number of persons whom he believed to be following him everywhere, blasting his character and making his life wretched. McNaughten had transacted business a short time before the deed, and had shown no obvious symptoms of insanity in his ordinary discourse and conduct. He was, however, acquitted on the ground of insanity. Thereupon the House of Lords, participating in the public alarm and indignation which were occasioned by the acquittal, propounded to the judges certain questions with regard to the law on the subject of insanity when it was alleged as a defense in criminal actions; the object being to obtain from them an authoritative exposition of the law for the future guidance of courts. The answers of the judges to the questions thus put to them constitute the law of England as it has been applied since to the defense of insanity in criminal trials.

It is not necessary to quote the questions and answers at length; the latter are somewhat confused, and the substance of them may be correctly given in fewer words. "To establish a defense on the ground of insanity, it must be clearly proved that at the time of committing the act the party accused was laboring under such a defect of reason from disease of the mind as not to know the nature and quality of the act he was doing, or, if he did know it, that he did not know he was doing what was wrong." It will not escape attention that the question of right and wrong in the abstract was here abandoned, being allowed quietly to go the way of the wild-beast form of the knowledge-test; the question of right and wrong was to be put in reference *to the par-*

unable to discern the essential identity of nature between a particular crime and all other crimes, whereby they are led to approve what, in general terms, they have already condemned. It is a fact, not calculated to increase our faith in the 'march of intellect,' that the very trait peculiarly characteristic of insanity has been seized upon as a conclusive proof of sanity in doubtful cases; and thus the infirmity that entitles one to protection, is tortured into a good and sufficient reason for completing his ruin."—("A Treatise on the Medical Jurisprudence of Insanity," fifth edition, pp. 26–28.)

ticular act with which the accused was charged. Moreover, it was to be put in reference to the particular act *at the time of committing it.* Did he at the time know the nature and quality of the act he was doing? These two points have been overlooked sometimes by hostile critics, who have condemned the rule enunciated, as though it referred to a knowledge of right and wrong generally. One may object to the rule as a bad one, and because it is calculated to mislead a jury, who are very likely to be misled by the existence of a general knowledge of right and wrong in the accused person to judge wrongly concerning his knowledge of the particular act at the time, but it must be allowed at the same time that it will, if strictly applied, cover and excuse many acts of insane violence. Of few insane persons who do violence can it be truly said that they have a full knowledge of the nature and quality of their acts at the time they are doing them. Can it be truly said of any person who acts under the influence of great passion that he has such a knowledge at the time?

The rule thus laid down, differing so much from that which was enunciated and mercilessly acted upon in Bellingham's sad case, was, however, limited in its application by a formidable exception. In reply to the question—"If a person, under an insane delusion as to existing facts, commits an offense in consequence thereof, is he thereby excused?"—the judges declared that "on the assumption that he labors under partial delusion only (whatever that may mean), and is not in other respects insane, he must be considered in the same situation as to responsibility as if the facts with respect to which the delusion exists were real. For example, if, under the influence of delusion, he supposes another man to be in the act of attempting to take his life, and he kills that man, as he supposes, in self-defense, he would be exempt from punishment. If his delusion was that the deceased had inflicted a serious injury to his character and fortune, and he killed him in revenge for such supposed injury, he would be liable to punishment." Here is an unhesitating assumption that a man, having an insane delusion, has the power to think and act in regard to it *reasonably;* that, at the time of the offense, he ought to have and to exercise the knowledge and self-control which a sane man would have and exercise, were the facts with respect to which the delusion exists real; that he is, in fact, bound to be reasonable in his unreason, sane in his insanity. The judges thus actually bar the application of the right-and-wrong criterion of responsibility to a particular case, by authoritatively prejudging it; instead of leaving the question to the jury, they determine it beforehand by assuming the possession of the requisite knowledge by the accused person. One of them, however, Mr. Justice Maule, so far dissented as to maintain that the general test of capacity to know right from wrong in the abstract ought to be applied to this case as to other cases.

But this is not all the uncertainty which appears in these answers.

In another part of them it is said, in reference to the same supposed case, that "notwithstanding the party accused did the act complained of with a view, under the influence of insane delusion, of redressing or revenging some supposed grievance or injury, or of producing some public benefit, he is nevertheless punishable, if he knew at the time of committing such crime that he was acting contrary to the law, by which is meant the law of the land." This answer really conflicts with a former answer; it is obvious that the knowledge of right and wrong is different from the knowledge of an act being contrary to the law of the land; and it is certain that an insane person may do an act which he knows to be contrary to law, because, by reason of his insanity, he believes it to be right, because, under the influence of insane delusion, he is a law unto himself, and deems it a duty to do it, perhaps "with a view of producing some public benefit."

The uprightness of English judges has happily been seldom called in question, but it may well be doubted whether the result of their solemn deliberations, as embodied in their answers to the questions put to them by the House of Lords, will commend their wisdom to the approbation of foreign nations and future ages. If it be true, as is sometimes said, that the verdict of foreign nations is an anticipation of the verdict of posterity, there are already sufficiently strong indications that their conclusions will be no honor to them in times to come. That they are unanimously condemned by all physicians who have a practical knowledge of the insane, may not affect the confidence of those who accept them, seeing that judges and physicians take such different stand-points; but when the judges of other countries condemn them with equal earnestness, it is impossible for the most confident to help feeling some hesitation. In the case of *State* v. *Jones*, tried in the court of New Hampshire, America, Judge Ladd, after passing in review the answers of the English judges, thus speaks of the doctrine embodied in them:

"The doctrine thus promulgated as law has found its way into the text-books, and has doubtless been largely received as the enunciation of a sound legal principle since that day. Yet it is probable that no ingenious student of the law ever read it for the first time without being shocked by its exquisite inhumanity. It practically holds a man, confessed to be insane, accountable for the exercise of the same reason, judgment, and controlling mental power, that are required in perfect mental health. It is, in effect, saying to the jury, the prisoner was mad when he committed the act, but he did not use sufficient reason in his madness. He killed a man because, under an insane delusion, he falsely believed the man had done him a great wrong, which was giving rein to a motive of revenge, and the act is murder. If he had killed a man only because, under an insane delusion, he falsely believed the man would kill him if he did not do so, that would have been giving the rein to an instinct of self-preservation, and would not be crime. It is true in words the judges attempt to guard against a consequence so shocking as that a man may be punished for an act which is purely the offspring and product of insanity, by introducing the quali-

fying phrase, 'and is not in other respects insane.' That is, if insanity produces the false belief, which is the prime cause of the act, but goes no further, then the accused is to be judged according to the character of motives which are presumed to spring up out of that part of the mind which has not been reached or affected by the delusion or the disease. This is very refined. It *may be* that mental disease sometimes takes a shape to meet the provisions of this ingenious formula; or, if no such case has ever yet existed, it is doubtless within the scope of Omnipotent power hereafter to strike with disease some human mind in such peculiar manner that the conditions will be fulfilled; and, when that is done, when it is certainly known that such a case has arisen, the rule may be applied without punishing a man for disease. That is, when we can certainly know that although the false belief on which the prisoner acted was the product of mental disease, still that the mind was in no other way impaired or affected, and that the *motive* to the act did certainly take its rise in some portion of the mind that was yet in perfect health, the rule may be applied without any apparent wrong. But it is a rule which can safely be applied in practice that we are seeking; and to say that an act which grows wholly out of an insane belief that some great wrong has been inflicted, is at the same time produced by a spirit of revenge springing from some portion or corner of the mind that has not been reached by the disease, is laying down a pathological and psychological fact which no human intelligence can ever know to be true, and which, if it were true, would not be *law*, but pure matter of fact. No such distinction ever can or ever will be drawn into practice; and the absurdity as well as the inhumanity of the rule seems to me sufficiently apparent without further comment. . . . It is a question of fact whether any universal test exists, and it is also a question of fact what that test is, if any there be."[1]

Since the answers of the judges were made to the House of Lords, the law as relating to insanity in a criminal trial has been laid down in conformity with their conclusions: if the accused person at the time of committing the offense knew right from wrong, and that he was doing wrong, he must be brought in guilty, whether insane or not. If insane, he is not necessarily exempted from the punishment of his crime; the question is, whether he was at the time capable of committing a crime; and that must be determined by evidence of the absence, not of insanity, but of a knowledge of right and wrong. Was his insanity of such a kind as to render him irresponsible by destroying his knowledge of right and wrong? Nevertheless, juries often, and judges occasionally, out of a natural humanity repudiate this dogma in particular cases, and, so far from any certainty of result having been secured by its application, it is notorious that the acquittal or conviction of a prisoner, when insanity is alleged, is a matter of chance. Were the issue to be decided by tossing up a shilling, instead of by the grave procedure of a trial in court, it could hardly be more uncertain. The less insane person sometimes escapes, while the more insane person is sometimes hanged; one man laboring under a particular form of derangement is acquitted at one trial, while another having an exactly similar form of derangement is convicted at another trial. No

[1] *State* v. *Jones*, p. 388.

one will be found to uphold this state of things as satisfactory, although there is great difference of opinion as to the cause of the uncertainty; the lawyers asserting that it is owing to the fanciful theories of medical men who never fail to find insanity where they earnestly look for it, the latter protesting that it is owing to the unjust and absurd criterion of responsibility which is sanctioned by the law. Meanwhile, it is plain that, under the present system, the judge does actually withdraw from the consideration of the jury some of the essential facts, by laying down authoritatively a rule of law which prejudges them; the medical men testify to facts of their observation in a matter in which they alone have adequate opportunities of observation; the judge, instead of submitting these facts to the jury for them to come to a verdict upon, repudiates them by the authority of a so-called rule of law, which is not rightly law, but is really false inference founded on insufficient observation.

In America it would seem that matters have been little better than they are in this country, the practice of the courts, like that of the British courts, having been diverse and fluctuating. In many instances juries have been instructed, in accordance with English legal authorities, that, if the prisoner, at the time of committing the act, knew the nature and quality of it, and that in doing it he was doing wrong, he must be held responsible, notwithstanding that on some subjects he may have been insane; that, in order to exempt a person from punishment, insanity must be so great in extent or degree as to destroy his capacity of distinguishing between right and wrong in regard to the particular act. But in other instances the instructions of the judges have been different. In the case of *State* v. *Wier*, Grafton, 60, 1864, Chief-Justice Bell charged the jury thus:

"The evidence must satisfy the jury that the party at the time of committing the act in question was insane, and that the disease is of such severity that the person is incapable of distinguishing between right and wrong in that particular case, or of controlling the sudden impulse of his own disordered mind; or, as the same rule has been laid down by an eminent judge, a person, in order to be punishable by law, must have sufficient memory, intelligence, reason, and will, to enable him to distinguish between right and wrong in regard to the particular act about to be done, to know and understand that it will be wrong, and that he will deserve punishment by committing it; to *which* I add *sufficient mental power to control the sudden impulses of his own disordered mind.* . . . I have been accustomed to regard as the *distinguishing test* of insanity *the inability to control the actions of a man's mind.* . . . The power of the control of the thoughts being lost, the power of the will over the conduct may be equally lost, and the party under the influence of disease acts not as a rational being, but under the blind influence of evil thoughts which he can neither regulate nor control. It was, perhaps, not without reason that in ancient times the insane were spoken of as possessed of an evil spirit, or possessed with a devil, so foreign are the impulses of that evil spirit to all the natural promptings of the sane heart and mind."[1]

[1] Quoted in the Report of *State* v. *Jones*, pp. 376, 377.

In the case of *Stevens* v. *The State of Indiana*, the instruction to the jury, that, if they believed the defendant knew the difference between right and wrong in respect to the act in question, if he was conscious that such act was one which he ought not to do, he was responsible—was held to be erroneous.

It would appear, then, that the American courts, which, having inherited the common law of England, at first followed docilely in the wake of the English courts, are now exhibiting a disposition to emancipate themselves from an authority which they perceive to be founded on defective and erroneous views of insanity, and a desire to bring the law more into accordance with the results of scientific observation. The decisions of the court of New Hampshire in *Boardman* v. *Woodman*, *State* v. *Jones*, and *State* v. *Pike*, are especially worthy of attention for their searching discussion of the relations of insanity to jurisprudence, and for the decisive abandonment of the right-and-wrong test of responsibility. In the case of *State* v. *Pike*, Chief-Justice Perley instructed the jury that they should return a verdict of not guilty "if the killing was the offspring of mental disease in the defendant; that neither delusion nor knowledge of right and wrong, nor design or cunning in planning and executing the killing, and in escaping or avoiding detection, nor ability to recognize acquaintance, or to labor or transact business or manage affairs, is, as a matter of law, a test of mental disease; but that all symptoms and all tests of mental disease are purely matters of fact to be determined by the jury."

"A striking and conspicuous want of success," said Judge Doe in the same case, "has attended the efforts made to adjust the legal relations of mental disease. . . . It was for a long time supposed that men, however insane, if they knew an act to be wrong, could refrain from doing it. But whether that suspicion is correct or not is a pure question of fact; in other words, a medical supposition—in other words, a medical theory. Whether it originated in the medical or any other profession, or in the general notions of mankind, is immaterial. It is as medical in its nature as the opposite theory. The knowledge-test in all its forms, and the delusion-test, are medical theories introduced in immature stages of science, in the dim light of earlier times, and subsequently, upon more extensive observations and more critical examinations, repudiated by the medical profession. But legal tribunals have claimed these tests as immutable principles of law, and have fancied they were abundantly vindicated by a sweeping denunciation of medical theories—unconscious that this aggressive defense was an irresistible assault on their own position. . . . In this manner, opinions, purely medical and pathological in their character, relating entirely to questions of fact, and full of errors, as medical experts now testify, passed into books of law, and acquired the force of judicial decisions. Defective medical theories usurped the position of common-law principles. . . . Whether the old or the new medical theories are correct is a question of fact for the jury; it is not the business of the court to know whether any of them are correct. The law does not change with every advance of science; nor does it maintain a fantastic consistency by adhering to medical mistakes which science has corrected. The legal principle, however much it may formerly have been obscured by patho-

logical darkness and confusion, is that a product of mental disease is not a contract, a will, or a crime. It is often difficult to ascertain whether an individual has a mental disease, and whether an act was the product of that disease; but these difficulties arise from the nature of the facts to be investigated, and not from the law; they are practical difficulties to be solved by the jury, and not legal difficulties for the court."

These American decisions are certainly an advance on any judgment concerning insanity which has been given in this country; they put in a proper light the relations of medical observation and law in questions of mental disease; and it cannot be doubted that future progress will be along the path which they have marked out. The question which will probably be submitted to the jury will be substantially, Was the act the offspring or product of mental disease?—and it will be seen that to lay down any so-called test of responsibility, founded on a supposed knowledge of right and wrong, is, as Judge Ladd remarked in *State* v. *Jones*, "an interference with the province of the jury, and the enunciation of a proposition which, in its essence, is not law, and which could not in any view safely be given to the jury as a rule for their guidance, because, for aught we can know, it may be false in fact." Seeing, then, that, by the unanimous testimony of medical men of all countries who have been practically acquainted with insanity, it is declared positively that such a proposition is false in fact, it is clear that the law, in enunciating it, is not only overstepping its rightful function, but actually perpetrating an injustice. It is simply doing in regard to insanity what it did formerly in regard to witchcraft—giving erroneous opinions on matters of fact to the jury under the name of law, and with all the weight of judicial authority. In one of the latest trials for witchcraft in this country, Lord Hale, whose crude dicta concerning insanity were so long acted upon in our courts of justice, instructed the jury: "That there are such creatures as witches he made no doubt at all. For, first, the Scriptures had affirmed so much. Secondly, the wisdom of all nations had provided laws against such persons, which is an argument of their confidence of such a crime." The jury accordingly found a verdict of guilty; the judge, satisfied with it, condemned the prisoners to death, and they were executed. It is one of the last executions for witchcraft in this country, for it occurred at a time—and this should never be forgotten—when the belief in witchcraft was condemned by the enlightened opinion of the country. As it was then with witchcraft, so it is now with insanity: the judge instructs the jury wrongly on matters of fact; they find accordingly a verdict of guilty; he is satisfied with the verdict, and an insane person is executed.

The falseness of the legal position will appear at once if we suppose a case of poisoning instead of a case of mental derangement: what would be thought of a judge who, when medical evidence of poisoning was given, should instruct the jury, as a principle of law,

that they must be governed in their verdict by the presence or absence of a particular symptom? "If the tests of insanity are matters of law, the practice of allowing experts to testify what they are should be discontinued; if they are matters of fact, the judge should no longer testify without being sworn as a witness, and showing himself qualified to testify as an expert."[1] But, in truth, the tests of insanity are no more matters of law than are the tests of a poison or the symptoms of disease. "If a jury were instructed that certain manifestations were symptoms or tests of consumption, cholera, congestion, or poison, a verdict rendered in accordance with such instructions would be set aside, not because they were not correct, but because the question of their correctness was one of fact to be determined by the jury upon evidence."[2]

Other nations have not bound themselves by so narrow and ill-founded a criterion of responsibility in insanity; they have refrained from the attempt to define exactly the conditions of responsibility. In France the article of the penal code is: "There can be no crime nor offense if the accused was in a state of madness at the time of the act." And the revised statutes of the State of New York enact that "no act done by a person in a state of insanity can be punished as an offense." These general enactments, while wisely leaving each case to be decided on its merits, may clearly be construed, if they were not intended, to exempt from punishment the individual who, being partially insane, nevertheless commits a crime which is no way connected with his insanity; who, in fact, so far as can be judged, does it in the same way and from exactly the same motive as a sane person. For an insane person is not exempt from the ordinary evil passions of human nature; he may do an act out of jealousy, avarice, or revenge: is it right, then, when, so far as appears, the passion is not connected with his diseased ideas or feelings, and he acts with criminal intent, that he should escape punishment for what he has done? This is really the important question which must continue to puzzle courts of justice when a particular criterion of responsibility is no longer laid down; for if it be admitted that an insane person who apparently does a criminal act sanely ought not to escape punishment, the difficulty of deciding whether his disease did or did not affect the act will remain. There will always be room enough for doubts and differences of opinion.

The section of the latest German penal code is: "An act is not punishable when the person at the time of doing it was in a state of unconsciousness or of disease of mind, by which a free determination of the will was excluded." Not every disorder of mind is exempt; only such actual disease as excludes a free determination of the will. The problem, then, is, to determine, first, what conditions of derangement of the mental faculties are to be considered as the result of dis-

[1] Judge Doe, *State* v. *Pike*. [2] *Boardman* v. *Woodman*.

ease; and, secondly, whether and how far free-will is excluded by them. In the case of a partially insane person acting to all appearances from an ordinary criminal motive, the act must be weighed in relation to these two questions; and, if they are answered in the negative, he would clearly be amenable to punishment.

It is abundantly evident from this short review of the codes of other countries that nothing can be said in justification of the superstitious reverence with which English lawyers cling to their criterion of responsibility. It is hard to see why they should suffer a greater pang in giving up this formula than they did in giving up other formulas which, having had their day and done much evil work, were abandoned. The "wild-beast theory," once so sacred, has been relegated to the record of human mistakes; the theory of a knowledge of right and wrong in the abstract which followed it was, in like manner, repudiated as men became better acquainted with the phenomena of mental derangement; surely, then, the metaphysical theory of a knowledge of right and wrong in relation to the particular offense, which finds little or no favor out of England, and which is condemned unanimously by all persons, in all countries, who have made insanity their study, may be suffered to join its predecessors, without danger of injury to what all those who approve and those who disapprove it desire — the strict administration of justice. Physicians have no right to interfere in the administration of the law, which is the judge's function, nor is it their duty to decide upon what is necessary to the welfare of the state, that being the legislator's work; their concern is with the individual, not with the citizen. But they plainly have the right to declare that the nature of a crime involves two elements: first, the knowledge of its being an act contrary to law; and, secondly, the will to do or to forbear doing it, and to point out that there are some insane persons who, having the former, are deprived by their disease of the latter; who may know an act to be unlawful but may be impelled to do it by a conviction or an impulse which they have not the will or the power to resist. Recognizing the obvious difference between him who *will* not and him who *cannot* fulfill the claims of the law, it is their function to point out the conditions of disease which constitute incapacity, and, when they find a false fact solemnly enunciated as a rule of law, to bring forward into all the prominence they can the contradictory instances which their observation makes known to them. "That cannot be a fact in law which is not a fact in science; that cannot be health in law which is disease in fact. And it is unfortunate that courts should maintain a contest with science and the laws of Nature upon a question of fact which is within the province of science and outside the domain of law."[1]

[1] Judge Doe, *Boardman* v. *Woodman*. "If it is necessary that the law should entertain a single medical opinion concerning a single disease, it is not necessary that that opinion should be a cast-off theory of physicians of a former generation."—(P. 150.)

OBSERVATIONS OF A NATURALIST IN NICARAGUA.

MR. CHARLES BELT has given us, in an interesting volume, the results of his natural history studies during a residence of four years in Nicaragua. His opportunities were excellent, and he has the faculty of turning them to good account. He found the climate of the region of almost uninterrupted summer, with abundant rainfall excepting in localities on the western slopes of mountains, and consequently a great profusion of animal and vegetable forms of life.

The eastern belt of the country is described as one unbroken forest, where perennial moisture reigns in the soil, perennial summer in the air, and vegetation luxuriates in ceaseless activity. Unknown are the autumn tints of English woods and the unrivaled splendors of the foliage of Canada. The trees do not grow in clusters, like our firs and oaks, but crowd upon each other in unsocial rivalry, struggling to keep their upper branches and leaves in the sunlight. A vast network of cable-like plants entangles the trees, and gorgeous air-plants dangle everywhere.

The central belt is of elevated grounds and grassy savannahs, but the Pacific slope is of rich, deep soil of decomposing tufas, where tropical fruits are abundant and prolific. It is an interesting fact that the mountains show everywhere traces of former glaciers. Enormous bowlders, beds of bowlder-clay and unstratified gravels, and rocks with smoothed rounded surfaces, suggest the former presence of ice.

In the profusion of animal life the struggle for existence is intense and incessant, and Mr. Belt was at once impressed with the extent to which protective coloring and other mimetic resemblances were found to exist. Thus wasps and stinging ants have hosts of imitators among moths, beetles, and bugs. A curious longicorn beetle was found covered with long brown and black hairs, closely resembling hairy caterpillars, common in the bushes, but which birds are known not to touch. The well-known phasma, or leaf-insect, escapes danger and eludes observation by its wonderful resemblance to leaves; and one species of this insect, in its larval stage, is called the moss-insect, and so closely resembles the moss it inhabits as not to be distinguished from it unless disturbed. The same is true of spiders which assume a resemblance to the petals of flowers in which they hide.

A curious green lizard was common in the wild-canes and grass, having leaf-like expansions, on account of which it was with great difficulty detected; and a spider so closely resembled, in form and color, a black ant, that it was mistaken for that insect. It had, moreover a habit of elevating its fore-legs so as to exactly resemble antennæ. Various species of stinging ants, which no bird would touch, were mimicked by spiders which were not distasteful to birds, as Mr. Belt proved.

So universal is protective resemblance among insects, in Nicaragua, that Mr. Belt was sure that whenever he found a species provided with special means of defense, others imitating it might be found also, and such indeed was the case invariably. It was noticed that insectivorous birds and mammals did not destroy the fire-flies, which were very abundant, and several insects, especially species of cockroaches, mimicked them, and in a perfectly fearless manner made themselves conspicuous, instead of resorting to hiding-places as is the custom of their tribe.

Those insects which were protected by special means of defense exposed themselves without fear, and rather made a display of their qualities. With the brilliant Heliconii butterflies, wasps of rich metallic lustre, fire-flies, and many other species, this was very obvious. Perhaps the display of their destructive features is a warning, otherwise they might be destroyed by their natural enemies, although not eaten. Thus a brilliantly-colored frog would come forth fearlessly during the day when others were concealed, and it was at once assumed that no animal would feed upon it; and, on offering it to fowls and poultry, not one would touch it excepting a duck, which at once threw it down and shook its head with evident dislike. Mr. Belt suggests that the white tail of the skunk laid upon its back makes it conspicuous in the dark, and may be a sort of warning to animals which would do it injury.

A most interesting instance of mimetic appearance and habit was afforded by a green, leaf-like locust. This insect would remain perfectly motionless, exactly resembling a leaf, while its enemies, a species of foraging ants, would run over it, and around it, destroying every insect in their way. The locust might be taken up and dropped again among the ants, still motionless as if dead, thus escaping injury.

These wonderful features in animal life had previously been studied by Mr. Bates in his researches in the valley of the Amazon, and by Mr. Wallace in several works, and strikingly illustrate the possibility of change in the structure and habits of living creatures. If this were not the case, how surely all types of animals and plants would disappear with the change of their environment! Mr. Belt calls attention to the fact that we are not to understand that one animal's imitating another is a conscious act. Perhaps we know very little of consciousness in these lowly creatures, but it is quite certain that they are conscious of danger, experience fear, and impulse to seek safety. Nor can we doubt that in these may originate those modifications which inaugurate protective resemblances which afterward become so marked. Natural selection is the present and efficient means by which the modified forms are preserved; those most favorably modified most readily escape destruction, and thus the fittest survive amid inevitable dangers.

Perhaps all insects have natural enemies which they fear, and this instinct of self-preservation is active and acute; and it would be

strange indeed if these conditions found no expression in those modifications of both form and habit which secure safety to the creature, and afford means of defense as well as of attack.

The well-known habit of animals in making their nests or burrows in places of safety was noticed in a species of birds which build their nests in bushes infested by stinging ants: a small parrot builds in a hole made in the nests of the termites, and a small fly-catcher builds alongside of the nests of one of the wasps.

The account given of the foraging ants (*Ecitons*) is most interesting. They live solely on insects and similar prey; ransack houses, and clear them of insects of every kind. They appear to be without fixed abodes, and advance in columns three or four yards wide, with flank, advance, and rear columns, millions in number. Their presence is announced by the noise of birds, as trogons, ant-thrushes, and others, which follow them for the insects which take wing, terrified by their destroyers. Grasshoppers, cockroaches, and others, are seized, bitten in pieces, and the fragments conveyed to the rear of the columns.

The temporary abodes of these ants seem to be a crevice or dense mass of brushwood, but in a few days they are off to new grounds. Small parties ascend trees in search of wasps' nests, and, if found, information is conveyed to the swarms below, when a column ascends, takes possession of the nest, and devours or removes the young, the wasps being powerless before the multitude.

While ants which hunt singly have eyes well developed, the eyes of the *Ecitons* are small, imperfect, and in some species wanting, and they evidently follow each other by scent. This was shown in the following manner: A party or column following a leader will become distracted if his track, which they will follow in its minutest windings, is interfered with. Mr. Belt scraped away the clay which the leader had gone over, and the followers were completely at fault until they had gone around the scraped portion, when, on striking the trail again, their hesitation vanished, and they followed it with the greatest confidence.

They aid each other in difficulty with a sympathy and intelligence that are extraordinary, and overcome dangers of very rare occurrence. On one being partially buried with atoms of clay, the others removed them; a small lump, too heavy for them to move, was instantly bitten to pieces, a dozen or more being summoned to assist. They aid each other in ascending steep places, in crossing water, and in every movement afford evidence of wonderful social order.

Not less interesting than these were the leaf-cutting ants (*Œcodoma*), common in tropical America. Their order, sagacity, and underground abodes, were a subject of wonder and study. All introduced species of trees are directly attacked by them, and, unless carefully watched, are destroyed. Mr. Belt turned the tide of war by pouring a strong solution of carbolic acid, in water, into their formicaries; straightway

the hosts left his plants to attend to home-affairs, and the removal of dead ants, food, and undeveloped larvæ and pupæ from their dwellings to a new home, was carried on with extraordinary zeal. The old burrow was deserted, and their ravages for a time suppressed. Corrosive sublimate makes the ants mad and furious. A little of the powder was sprinkled in one of their paths; so soon as the ants touched it, they ran wildly about attacking others, and very soon compact masses, or balls of ants, would be found biting each other. Huge fellows from the formicaries, measuring three-quarters of an inch in length, came forth to set matters right, but on touching the poison their bravery forsook them. They attacked others, and were themselves attacked, and became the centres of balls of furious ants.

Many indigenous trees escape their ravages, evidently because distasteful. Through long ages the ants and trees of tropical America have become somewhat modified together. All plants disliked by ants have a great advantage over others, and thus a selection has gone on, in which introduced species do not share. The lime is less liked than the orange or the citron, and, while these are inevitably destroyed, unless protected, the lime would probably survive; and Mr. Belt judiciously remarks that a little more or less acridity, or a slight chemical difference in the composition of the tissues of a leaf, so small that it is inappreciable to our senses, may be sufficient to insure the preservation or the destruction of a species throughout an entire continent. The paths of these ants ramify in every direction from their abodes, and are more thronged than the streets of London. They seek the open spaces near margins of the forest, and excavate a series of galleries, which are the scene of manifold operations. Continually the workers bring in burdens consisting chiefly of fragments of leaves. Naturalists have differed as to the use to which these leaves are put. Some suppose they are used as food, others, to line their galleries; the explanation given by Mr. Belt is, that the leaves are used as a manure, on which grows a minute fungus, which is the food of the ants; that they are, in reality, mushroom growers and eaters. This extraordinary conclusion he arrived at by careful observations. He repeatedly explored their nests, which are a series of rounded chambers about as large as a man's head, connected by tunneled passages leading from one chamber to another. In the burrows the leaves could never be found in quantity; they were evidently directly used up; but the chambers were about three-fourths filled with a speckled-brown, spongy-looking mass. Throughout this were ants with pupæ and larvæ. Upon careful examination, it proved to be minutely subdivided leaves, brown and withered, overgrown and lightly connected by a minute, white fungus, that ramified in every direction through it. This fungus was found in every chamber opened, and in the midst of it ant-nurses and immature ants. When the nests were disturbed, this fungus, or ant-food, was guarded with great care, and every atom of it

was removed as soon as possible, if the old abode was broken up. That the leaves were not eaten was shown by the fact that the refuse in many deserted chambers was composed entirely of their decayed fragments, exhausted as a manure for the fungus, and left as food for larvæ of several species of beetles. Some leaves were evidently unsuited to the purposes of the ants. Grass, if carried in, was directly brought out again, and thrown away. The carriers of this were probably young ants, and may have got a severe ear-wigging for their stupidity. After all, then, do ants, like hosts of other animals, learn by experience, and is instinct, so called, sometimes at fault?

Bates describes the sand-wasps, on the banks of the Amazon, which, on making a hole, carefully examine the locality before leaving it to procure food, and Mr. Belt noticed similar actions in repeated instances. They take the same precautions that a man would do, who wished to return to the same spot. Frequently, after going a few rods, they will return, fly around for an instant, and then dart away. On one occasion, a portion of a green caterpillar was carried away by a wasp, which, on returning for the other portion, missed its mark on alighting, and became quite lost, when it took wing again, made circles around the spot, and again alighted, but in vain. This was repeated half a dozen times, and the insect seemed to get angry, buzzing loudly, when finally it found its prey.

Butterflies of several kinds are described as abundant, but the migration in enormous swarms of one or more species, which occurred every year, is an interesting phenomenon.

Flights of butterflies were thus described by Darwin in 1832: "When off the shores of Northern Patagonia, we were surrounded by vast numbers of butterflies, in bands or flocks of countless myriads, extending as far as the eye could range; even with the aid of a telescope, it was not possible to see a space free from butterflies." Mr. Belt had seen immense migrating flocks in Brazil, journeying southeastward, as were all those seen by him in Nicaragua. These were a brown-tailed species (*Timetes chiron*), and there were no return-swarms, but a continuous migration in one direction only. The gilded, day-flying moth (*Urania leilus*), and a few yellow butterflies, were seen with the migrating hosts.

Birds, which are abundant at all seasons in the country, have a habit of associating, possibly for safety, or, as Mr. Belt suggests, to assist each other in hunting for food. Thus, flocks of hundreds, comprising a score of different species, are frequent, and, when present, the trees seem alive with them. He could scarcely go abroad without meeting them; fly-catchers, woodpeckers, tanagers, creepers, trogons of several species, all associating, apparently, on the most friendly terms, for mutual help.

The natives found about the country, as well as in the towns, represent an inferior type of civilization. They are, as a rule, excessively

indolent and thriftless, the mixed races much more so than the native Indians. Idleness is the curse of Central America, and the people are content to live in squalid poverty rather than work. Dio Filiberto was a thrifty man, and told the traveler that he was building a new residence, and showed him outside his hut four old posts, used for tying cows to, which had evidently been in the ground many years. "There," said he, "are the corner-posts, and I shall roof it with tiles." Long, no doubt, will he lounge at evening, when his wife and children are milking the cows, and feel proud, as he views the four old posts, that he is building a new house.

The habitations of the Indians, mere shelters as they are, are generally quite cleanly; and this class of the population is invariably fond of flowers. On all important occasions, beautiful and fragrant flowers are used for decoration, a trait of the old Indians which survives with their unfortunate descendants.

Mr. Belt's descriptions of natural scenery are vivid and impressive. The night-world he describes as being very different from that of the day. Things that blink and hide from the light are all awake and astir when the sun goes down. Great spiders and scorpions prowl about, or take up advantageous positions where they expect their prey to pass. Cockroaches, of all sizes, from that of one's finger to that of one's finger-nail, stand with long, quivering antennæ, watching for their numerous foes, or scurry away from danger, as fast as their legs can carry them; but, if they come within reach of the great spider, they are pounced upon in an instant, and, with one convulsive kick, give up the struggle. Centipedes, wood-lice, and all kinds of creeping things, come out of cracks and crevices; the pools are alive with water-beetles, which have been hiding in the ooze all day. Owls and night-jars make strange, unearthly cries. The timid deer comes out of its close covert to feed on the grassy clearings. Jaguars, ocelots, and opossums, slink about in the gloom. All the day-world is at rest and asleep. The night speeds on; the dawn is saluted by the song of birds, and the creatures of night hurry to their dens and hiding-places. As a traveler, naturalist, and observer, Mr. Belt has done excellent service, and the reading world is his debtor.

A GIGANTIC RELIC.

By H. BUTTERWORTH.

THE rarest collections of scientific relics are often the most unvisited, and it is a somewhat singular fact, that the choicest and most instructive curiosities in many of our larger cities are not to be found in the popular museums. Thousands of people living in the city of Boston, who are familiar with the stuffed animals and astonishing

wax figures in the old Boston Museum, and are accustomed to air their fancy among the respectable fossils and gorgeous tropical birds in the Museum of Natural History, have perhaps never so much as heard of the wonder-exciting collection of anatomical curiosities known as the Warren Museum. The building stands on Chestnut Street, a quiet, tenantless alley, running from Charles Street to the Charles River, but a few steps from Beacon Street and the Public Garden. It is made of brick, with heavy iron doors and shutters, and of all places would be the least likely to attract the eye of the stranger, but for the inscription over the door—

"ERECTED BY

DR. JOHN COLLINS WARREN."

Dr. John Collins Warren was the son of Dr. John Warren, a most skillful surgeon in the American army during the Revolutionary War, and the founder of the medical school in Harvard College. He was educated in the best medical schools of London and Paris, and, on the death of his father, in 1815, was elected Professor of Anatomy and Surgery at Harvard College, and in 1820 was placed at the head of the surgical department of the Massachusetts General Hospital, a position that he held for thirty-three years. During the latter period he made the most extensive collection of anatomical specimens to be found in the country. A part of these are still at the Massachusetts General Hospital, a part at the Boston Museum of Natural History, and a part, comprising the rarest and most valuable, constitute the Warren Museum.

The museum belongs to Dr. Warren's heirs. For a considerable period after his decease, they used to open it on certain days to the public, but it ceased to excite curiosity, and it is now only opened by special permission, on application to members of the family. Every courtesy is extended to those who wish to visit the place for scientific purposes, although no provision was made in Dr. Warren's will for the preservation of the relics or care of the building.

The curiosities collected by Dr. Warren, which are to be seen in the Boston Museum of Natural History, are comparatively unimportant. The biography of the highwayman, Walton, bound in his own skin, attracts the lovers of sensation, and the cast of the French horned lady, and the skeletons of certain rickety Indians, seem to be particularly appetizing to children. The anatomical specimens, showing how near a person may come to death, and yet escape, are, however, interesting. Among these, is the cranium of the once famous Vermonter, who lived twelve years and a half after the passage of an iron bar through his head, the consequence of an accident in blasting rocks. He used to travel about New England, exhibiting himself and his bar. He died in California about the year 1860. The bar was three feet

seven inches in length, and 1¼ inch in diameter, and weighed 13¼ pounds. It is placed near the cranium, in the museum.

The Warren Museum consists of two fire-proof rooms, one of which contains gigantic fossils, and the other, relics which the great anatomist wished to preserve with more than ordinary care. Among these are the skull, brain, and heart of Spurzheim, the phrenologist and anatomist, who died in Boston in 1832, and whose monument graces one of the principal avenues of Mount Auburn.

Spurzheim was a martyr to science, and those who were familiar with his self-forgetful life, and the vicissitudes of his career, could hardly view these relics with unmoistened eyes. The heart is preserved in a glass jar of alcohol, and the brain in a glass box filled with liquid. The Prussian philosopher died only two months after his arrival in Boston, during the delivery of his first course of lectures. He gave his body to science, to which, from boyhood, he had devoted all the energies of his soul.

The most remarkable object in the Warren Museum is the largest skeleton of the *Mastodon giganteus* ever discovered on the continent. By its side, in way of contrast, is the frame of the elephant Pizarro, the largest ever brought to this country. The skeleton of the *Mastodon giganteus* will not fail to cause the visitor to start back in awe, and he will be hardly able to suppress that adjective of fools, "Impossible!" It is twelve feet high, and thirty-four feet in length, from the tips of the tusks to the extremity of its tail. Its trunk is seventeen feet in length. The animal must have weighed more than 20,000 pounds!

Dr. Warren, in his magnificent and very costly work on the *Mastodon giganteus*, copies of which are only to be found in the rarest libraries, has given us an account of all that is known of this animal, and a very interesting description of the finding of this particular specimen, of which we make an abridgment:

At a very early period after the settlement of this country, relics of the mastodon were found in the vicinity of the Hudson River. Among these were a tooth, which is described by Dr. Cotton Mather, of Boston, as weighing more than four pounds, and a thigh-bone, said to have been more than seventeen feet long.

As the country became settled, mastodon-bones, in greater or less numbers, were found scattered over a large part of the territory of the United States, but chiefly near the Hudson, in the salt-licks of Kentucky, in the Carolinas, in Mississippi and Arkansas. They have recently been found in California and Oregon.

The Hudson River country, between New York and Albany, seems to have been a favorite resort of the mastodon race. The lands here were fertile, undulating, and well wooded, and the valleys contained lacustrine deposits, favorable to the growth of such trees and shrubs as would be likely to afford this animal subsistence.

In the year 1845 there was found, at Newburg, on the Hudson, the largest perfect skeleton of a mastodon which has yet been exhumed on this continent. The summer had been exceedingly hot and dry. Many small lacustrine deposits had been exposed by the drought, and the farmers had industriously seized upon the opportunity to remove these rich beds of fertility to their tillage-lands and fields.

The drought at last laid bare one of these deposits in a bog on the farm of Mr. N. Brewster, a spot that had never been known to become dry before. Mr. Brewster at once summoned his men to remove the deposit, as rapidly as possible, to his fields and farm-yards. One day, toward evening, in the latter part of summer, these laborers struck a hard substance. Some said it was "a rock;" others, a "log;" others, jestingly, "a mammoth."

Early the next morning, Mr. Brewster went with his laborers to the field, and found the supposed rock or log to be an immense bone. The men began digging, full of eager curiosity, and exposed to view the massive skull and long white tusks of a mastodon. These tusks were of such immense size and length as to cause the most wonderful reports to go flying about the neighborhood, and to draw the good people of Newburg in crowds to the place. It was soon discovered that the perfect skeleton of a mastodon was embedded in the peat. Sheer-poles and tackles were obtained, and, amid excitement, cheering, and many cautions, the bones of the monster were raised from the bed where they had lain no one can tell how many thousand years.

Two days were occupied in these interesting labors. The relics drew to them an immense number of people from the surrounding country. Beneath the pelvic bones of this mastodon were found five or six bushels of broken twigs, which evidently had constituted the animal's last meal. He had undoubtedly been mired while attempting to cross this bog, and in this manner perished. These twigs were from one-quarter to three-eighths of an inch in diameter, and a little more than an inch in length. They were supposed to belong to the willow, linden, and maple trees.

It is impossible to conjecture how many years ago this creature may have lived. What marvelous scenes must have passed before its eyes in its wanderings! What gigantic forests; what noble water-courses; what luxurious vegetation; what strange animals may have been its companions—species that passed away long before civilization brought its destructive weapons to the Western shores! Was man, too, its contemporary; if so, how humiliating to intellectual pride is the oblivion that consigns to conjecture and mystery so large a portion of the human race!

EVOLUTION AND THE DOCTRINE OF DESIGN.[1]

By W. STANLEY JEVONS, F.R.S.

VERY profound philosophers have lately generalized concerning the production of living forms, and the mental and moral phenomena regarded as their highest development. Mr. Herbert Spencer's theory of Evolution purports to explain the origin of all specific differences, so that not even the rise of a Homer or a Beethoven would escape from his broad theories. The homogeneous is unstable and must differentiate itself, says Spencer, and hence comes the variety of human institutions and characters. In order that a living form shall continue to exist and propagate its kind, says Mr. Darwin, it must be suitable to its circumstances, and the most suitable forms will prevail over and extirpate those which are less suitable. From these fruitful ideas are developed theories of evolution and natural selection which go far toward accounting for the existence of immense numbers of living creatures—plants and animals. Apparent adaptations of organs and limbs to useful purposes, which Paley and other theologians regarded as distinct products of creative intelligence, are now seen to follow as natural effects of a constantly-acting tendency. Even man, according to these theories, is no distinct creation, but rather an extreme specimen of brain-development. His nearest cousins are the apes, and his pedigree extends backward until it joins that of the lowliest zoophytes.

The theories of Darwin and Spencer are doubtless not demonstrated; they are, to some extent, hypothetical, just as all the theories of physical science are to some extent hypothetical, and open to doubt. But I venture to look upon the theories of evolution and natural selection, in their main features, as two of the most probable hypotheses ever proposed, harmonizing and explaining, as they do, immense numbers of diverse facts. I question whether any scientific works which have appeared since the "Principia" of Newton are comparable in importance with those of Darwin and Spencer, revolutionizing, as they do, all our views of the origin of bodily, mental, moral, and social phenomena.

Granting all this, I cannot for a moment admit that the theory of Evolution will alter our theological views. That theory embraces several laws, or uniformities, which are observed to be true in the production of living forms; but these laws do not determine the size and figure of living creatures, any more than the law of gravitation determines the magnitudes and distances of the planets. Suppose that Darwin is correct in saying that man is descended from the Ascidians;

[1] Abstracted from the closing chapter of "The Principles of Science: A Treatise on Logic and Scientific Method."

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yet the precise form of the human body must have been influenced by an infinite train of circumstances affecting the reproduction, growth, and health, of the whole chain of intermediate beings. No doubt, the circumstances being what they were, man could not be otherwise than he is; and, if, in any other part of the universe an exactly similar earth, furnished with exactly similar germs of life, existed, a race must have grown up there exactly similar to the human race.

By a different distribution of atoms in the primeval world, a different series of living forms on this earth must have been produced. From the same causes acting according to the same laws, the same results will follow; but from different causes acting according to the same laws, different results will follow. So far as we can see, then, infinitely diverse living creatures might have been created consistently with the theory of evolution, and the precise reason why we have a backbone, two hands with opposable thumbs, an erect stature, a complex brain, two hundred and twenty-three bones, and many other peculiarities, is only to be found in the original act of creation. I do not, any less than Paley, believe that the eye of man manifests design. I believe that the eye was gradually developed; and we can, in fact, trace its gradual development from the first germ of a nerve affected by light-rays in some simple zoophyte. In proportion as the eye became a more delicate and accurate instrument of vision, it enabled its possessor to escape destruction; but the ultimate result must have been contained in the aggregate of the causes, and these causes, so far as we can see, were subject to the arbitrary choice of the Creator.

Although Prof. Agassiz is clearly wrong in holding that every species of animals or plants has appeared on earth by the immediate intervention of the Creator, which would amount to saying that no laws of connection between forms are discoverable, yet he seems to be right in asserting that living forms are entirely distinct from those produced from purely physical causes. "The products of what are commonly called physical agents," he says,[1] "are everywhere the same (i. e., upon the whole surface of the earth), and have always been the same (i. e., during all geological periods); while organized beings are everywhere different and have differed in all ages. Between two such series of phenomena there can be no causal or genetic connection." Living forms, as we now regard them, are essentially variable. Now, from constant mechanical causes, constant effects would ensue. If vegetable cells are formed on geometrical principles, being first spherical, and then by mutual compression dodecahedral, then all cells should have similar forms. In the *Foraminifera* and some other of the more lowly organisms, we do seem to observe the production of complex forms on pure geometrical principles. But from similar causes, acting according to similar laws and principles, only similar results could be produced. If the original life-germ of each creature is a

[1] Agassiz's "Essay on Classification," p. 75.

simple particle of protoplasm, unendowed with any distinctive forces, then the whole of the complex phenomena of animal and vegetable life are effects without causes. Protoplasm may be chemically the same substance, and the germ-cell of a man and of a fish may be apparently the same, so far as the microscope can decide; but if certain cells produce men, and others as uniformly produce a given species of fish, there must be a hidden constitution determining the extremely different results. If this were not so, the generation of every living creature from the uniform germ would have to be regarded as a distinct act of arbitrary creation.

Theologians have dreaded the establishment of the theories of Darwin and Spencer, as if they thought that those theories could explain every thing upon the purest mechanical and material principles, and exclude all notions of design. They do not see that those theories have opened up more questions than they have closed. The doctrine of Evolution gives a complete explanation of no single living form. While showing the general principles which prevail in the variation of living creatures, it only points out the infinite complexity of the causes and circumstances which have led to the present state of things. Any one of Mr. Darwin's books, admirable though they all are, consists but in the setting forth of a multitude of indeterminate problems. He proves in the most beautiful manner, that each flower of an orchid is adapted to some insect which frequents and fertilizes it, and these adaptations are but a few cases of those immensely numerous ones which have occurred throughout the life of plants and animals. But why orchids should have been formed so differently from other plants, why any thing, indeed, should be as it is, rather than in some of the other infinitely numerous possible modes of existence, he can never show. The origin of every thing that exists is wrapped up in the past history of the universe. At some one or more points in past time there must have been arbitrary determinations which led to the production of things as they are.

THE following article, upon the same general subject, recently appeared in *Church and State:*

The last lecture in the course on "Christian Truth and Modern Opinion" was delivered in Christ Church, New York. The subject was, "Evolution and a Personal Creator." Dr. Smith commenced by saying that while he was very far from being an advocate for the theory of evolution, it was no part of his purpose to attempt its refutation. He expressed the opinion, judging from former conflicts between religious and scientific theories, and the evident tendency of scientific investigation and discovery, that not many years would pass away before some theory of evolution would be generally accepted by edu-

cated men as the most rational explanation of the phenomena of the universe. In the mean time the minds of many persons are seriously disturbed by the supposed antagonism of any such theory to the idea of a personal God, and therefore to the whole idea of natural and revealed religion. It is very important, therefore, that, in anticipation of the general acceptance of some such theory, it should be shown that it not only does not militate against the idea of a personal God, but that it is hostile to no interest of Christianity.

In carrying out this purpose, Dr. Smith said that he should seek, as a starting-point, some ground which could be held in common by theists who are without prejudice in regard to scientific investigation, and evolutionists who are ready to consider any evidence as to the Infinite Being behind and beyond the phenomena of Nature.

In seeking such common ground, Dr. Smith referred to that period, in the history of Nature, when space was filled with a homogeneous mass which the Greeks called *hylé*. Whether this was what we usually call matter, or immeasurably extended force-centres, made no difference in the argument. Beyond this *hyle*, and preceding it in the order of thought, is absolute being. The theist, of course, holds this. Mr. Herbert Spencer, the great leader of the evolutionists, holds it also. We must postulate absolute being, he says, as the condition of any conclusions as to phenomena. The evolutionist holds, however, that every thing in regard to absolute being is unknowable. If it is unknowable, then he can no more deny than affirm any thing in regard to it. Dr. Smith then said, that since the evolutionist, on his own principles, could not deny it, he should suppose, for the present, reserving the evidence for it until later in the discussion, that absolute being is personal being, with reason, affection, and will.

Dr. Smith then said that, having made this supposition, which no evolutionist could deny, we were prepared to witness the process of evolution, so far as such a process exists in Nature, remembering all the time that the whole process and every step in the process are simply expressions, according to our supposition, of the will and agency of the Absolute Being.

We find certain laws in Nature (which is only another name for methods of divine agency), by which this process of evolution is carried on. Such are the laws of the persistence of force, the continuity of motion, and the indestructibility of matter. The divine power, working according to these laws, builds up the system of the universe. Dr. Smith showed how, on the theory of evolution, the apparent chasm between inorganic and organic Nature might be passed over without disturbance or any different or peculiar divine agency. In other words, the process might be continuous without militating at all against the idea of the constant agency of a personal God. The evidence alleged by evolutionists that this is the case, and that the process comes finally to include men, was considered. The objections

also to this evidence were reviewed. In this connection Dr. Smith paid a high tribute to the scientific labors and the theistic principles and influence of Prof. Agassiz, expressing the conviction, at the same time, that Prof. Agassiz's scientific opinion as to the origin of species represented a failing cause.

The objection arising from the absence of uniting links in the fossiliferous remains of species was considered, and the refutation claimed to be made by the evolutionists was given in detail. This answer to the objection is found in the fact of the imperfection of the geological record, and the almost entire destruction of organic remains. The evolutionist claims that if it were not for the law by which less favored varieties of animal life disappeared, the breaks between species would not exist. Specific distinctions would be impossible. In this connection Dr. Smith considered the basis of specific classification, giving a review of the old controversy between nominalism and realism on this subject. He also pointed out how certain laws—such as those of the transmission of likeness to an original type; the tendency to variation; the increase of animal life in a geometrical ratio; and the consequent struggle for existence—would, according to the theory of evolution, give rise to the phenomena of specific distinction.

At this point Dr. Smith claimed that, if it should finally be established that this progress in Nature is continuous until it reaches and includes man, it would no more militate against the idea of a personal Creator than the fact that the process of evolution existed at all. If God has chosen that any part of the process shall be without distinct and special creative acts, there is no reason why the whole process may not be, and the continuous chain of evolution run back to the one original creative act. It must be remembered, however, that the argument proceeds all the time upon the supposition of an incessant and ubiquitous exercise of the will and the agency of a personal God, in every atom of matter, or every force-centre, and thus underlying and pervading the whole phenomenal universe.

As the theory of evolution touches only phenomena and the laws of their succession, it excludes no hypothesis as to what lies back of phenomena, and the existence of a personal God must be assailed, if assailed at all, upon other and metaphysical grounds.

Dr. Smith remarked that, although the subject assigned him required him to consider merely the relation between the theory of evolution and the doctrine of a personal Creator, yet, inasmuch as it was his desire to show that even if the theory is true it affects no interest of Christianity injuriously, he would say a word in regard to the Scriptural account of the creation. The interpretation of the Bible is more or less modified in each succeeding age, and is thus more and more correctly understood. The Bible has passed through the crisis of astronomical and geological investigation, and its authority is not only unimpaired, but is increased by the ease with which it is found

to be adapted to every stage of scientific progress. Certain peculiarities in Hebrew words used in describing the creation were here referred to.

Up to this point the existence of a personal Creator had been placed in the argument upon hypothetical ground. Dr. Smith then considered the evidence upon which this truth rests, drawing a distinction between the understanding and reason, affirming the intuitional power of reason and following the line of the great philosophers like Coleridge, Kant, Leibnitz, and Plato. A rational plan in the universe made every supposition irrational except that of a reason preceding phenomena and upon which phenomena rest.

Supposing, then, that the theory of evolution should finally be established, we find in Christianity the completion of the process, by the union of man with God in the Incarnation. This view, which presents all things as complete in Christ coming from Him and returning to Him, gives a grandeur to Nature which it cannot otherwise possess. Dr. Smith closed with a quotation from Coleridge's "Hymn in the Valley of Chamouny."

SKETCH OF DR. J. P. JOULE, F.R.S.

IF the discovery of chemical analysis by means of the spectrum be accepted as the most brilliant scientific achievement of the present century, the research by which the conservation of energy became established on a basis of exact quantitative experiment must be regarded as far more profound and important in its consequences. This great generalization, beyond doubt, is the property of no single intellect. Many men, in different countries, had independently arrived at the conception, and had furnished various kinds and degrees of evidence that it was true, but the honor of its first experimental demonstration, by which the quantitative convertibility of forces may be established, belongs to the subject of the following sketch.

James Prescott Joule was born at Salford, England, on Christmas-eve, 1818, and was privately educated at home. He early showed a taste for scientific study, and, at the age of fifteen, became a pupil of Dr. John Dalton, the chemist. This celebrated man—atomist and Quaker—came to Manchester, and became Professor of Mathematics and Natural Philosophy in the New College; and, when that was removed to York, he remained as a private teacher of the same subjects. By him, young Joule was initiated into mathematics, and trained in the art of experiment.

Mr. Joule's attention was early turned in a direction which naturally led him to his great discovery. At an early age he took up the

subject of electro-magnetic engines; the idea of using electricity as a motive power being then a favorite one among scientific men. He made inventions to employ electro-magnetic force as a motor, and his first scientific paper was upon this subject. But the result of his investigations was the abandonment of any expectation of obtaining a valuable power from electro-magnetism. But, while giving up the hope of arriving at any important economical conclusions, Mr. Joule continued his researches on the laws which govern the lifting and sustaining power of the electro-magnet. Early in 1841 he gave, in the form of a lecture in the Royal Victoria Gallery, Manchester, the result of his experiments on a new class of magnetic forces, with the preliminary statement of what had been done by M. Jacobi, of St. Petersburg, and himself, in the way of applying magnetism as a motive power. Mr. Jacobi, it may be remarked, is reputed to have been the first who constructed an electro-magnetic machine capable of producing continuous movement, and which was for a long time used in impelling a boat on the Neva.[1] Mr. Joule subsequently continued this investigation in conjunction with Dr. Scoresby, and from the results of their calculations it appeared that a grain of coal consumed by a steam-engine will raise 143 pounds one foot high, while a grain of zinc consumed in a voltaic battery can raise theoretically only 80 pounds. The cost of power by electro-magnetism was estimated to be twenty-five times greater than the cost of an equal amount of steam-power. Mr. Joule had arrived at the theory of the magnetic engine when twenty-one years of age, and in 1840 he had published a paper in Sturgeon's "Annals of Electricity," demonstrating that there is "no variation in economy, whatever the arrangement of the conducting metal, or whatever the size of the battery." Kindred to the subject of electro-motive machines is that of the air-engine, to which Mr. Joule gave considerable attention.

"Dr. Joule has pursued several lines of inquiry conjointly with other philosophers. His communication to the Royal Society, 'On the Changes of Temperature produced by the Rarefaction and Condensation of Air,' in which he pointed out the dynamical cause of the principal phenomena, and described the experiments on which his conclusions were founded, led Prof. Thomson, of Glasgow, to embark with Dr. Joule in a series of elaborate investigations 'On the Thermal Effects of Fluids in Motion.' The first of their series of four papers was read before the Royal Society, in June, 1853; the last in June, 1862. The whole will be found published at length in the 'Philosophical

[1] Since Jacobi's elaborate experiments, many other electro-motors have been constructed. The late Mr. Sturgeon, of Manchester, with whom Mr. Joule corresponded in his early inquiries, pumped water with an electro-magnet; Mr. Davidson, of Aberdeen, drove a turning-lathe by the same power; and in 1848 Sir David Brewster sailed at the rate of a mile an hour in a boat thus impelled, and constructed by Mr. Dillwin, of Swansea. In this country Messrs. Davenport and Cook investigated the subject.

Transactions.' Dr. Lyon Playfair and Dr. Joule have also published an account of a conjoint investigation into the volumes occupied by bodies, both in the solid form and when dissolved in water, and have obtained results of an unexpected nature as well as of great value. Among other curious results, they found that 'many salts, when dissolved in water, do not add to the bulk of the water more than is due to the water actually present in the salts.' They have further shown that 'when salts do add to the bulk of the water in which they are dissolved, the increase of the bulk corresponds to that of a volume, or some multiple of a volume of water.' "

Dr. Joule's inventive talent was early shown in the construction of galvanometers. In 1863 he described to the Manchester Society his new and extremely sensitive thermometer, which was able to detect the heat radiated by the moon. When the moonbeam passed gradually across the instrument, the index was deflected several degrees, first to the right and then to the left; thus showing that the air in the instrument had been heated a few ten-thousandths of a degree by the influence of the rays. These experiments were lately referred to by the present Earl Rosse in a lecture on the same subject delivered at the Royal Institution.

It was about 1840 that Dr. Joule began to direct his special attention to the subject of heat. He made a communication to the Royal Society in that year, announcing the discovery of a principle in the development of heat by the voltaic principle, in which he established relations between heat and chemical affinity. This paper is recognized as containing the germ of the subsequent unfoldings of dynamical science in relation to chemical action.

The old view of the nature of heat still prevailed, although the declarations of Bacon and Locke, and the researches of Rumford and Davy, had undermined the notion that heat was a subtile matter or material agent diffused throughout all bodies, and had prepared the way for its apprehension as a mode of molecular motion. The first noteworthy advance toward the establishment of the mechanical theory of heat was made by Séguin, a Frenchman, in 1839, and by Mayer, a German, in 1842, who had propounded the hypothesis that the heat evolved in compressing an elastic fluid is exactly equivalent to the compressing force. But the theory was not yet established upon an experimental basis, so as to command the assent of the scientific world.

Independently of what had been done by others, and working in his own line, Dr. Joule had established relations, as we have seen, between heat and chemical affinity in 1840, and, some two years later, he applied the dynamical theory to steam-engines, to electro-magnetic engines, to vital processes, and to chemistry. "His paper on the 'Electric Origin of Heat' was a first communication, in 1842, to the meeting of the British Association at Manchester—the last meeting,

by-the-way, at which Dalton appeared; and, on August 21, 1843, a circumstance which requires special mention, he communicated a second paper to the Association, then meeting at Cork, in which he describes a series of experiments on magneto-electricity, executed with a view to determine the mechanical value of heat. Experiments, with a like object, on the condensation of air, were communicated to the Association in 1844; and in 1845 his important paper, 'On the Mechanical Equivalent of Heat,' detailed the results he had gained from water agitated by a paddle-wheel. In following years, the same subject was perseveringly prosecuted, by numerous and yet more accurate experiments, until his grand determination was finally reached. In an elaborate paper, read before the Royal Society, January 21, 1849, and published in the 'Philosophical Transactions' of 1850, we have the results thus stated: 1. 'The quantity of heat produced by the friction of bodies, whether solid or liquid, is always proportional to the quantity of force expended;' 2. 'The quantity of heat capable of increasing the temperature of a pound of water by 1° Fahr., requires for its evolution the expenditure of a mechanical force required by the fall of 772 pounds through the space of one foot.'"

Dr. Tyndall gives the following explanation of the term "foot-pounds," used as a measure by Joule: "The quantity of heat which would raise one pound of water one degree in temperature is exactly equal to what would be generated if a pound-weight, after having fallen 772 feet, had its moving force destroyed by collision with the earth. Conversely, the amount of heat necessary to raise a pound of water one degree would, if applied mechanically, be competent to raise a pound-weight 772 feet high, or it would raise 772 pounds one foot high. The term 'foot-pound' expresses the lifting of one pound to the height of a foot. Thus the heat required to raise the temperature of one pound of water one degree being taken as a standard, 772 foot-pounds constitute what is called *the mechanical equivalent* of heat."

A sharp controversy arose a few years since in England as to the relative merits of Mayer and Joule in contributing to the establishment of the truth of the mechanical equivalent of heat. Dr. Joule states his own relation to the investigation as follows: "Mayer," he says, "appears to have published his views for the express purpose of securing priority. He did not wait until he had the opportunity of supporting them by facts. My course, on the contrary, was to publish only such theories as I had established by experiments calculated to commend them to the scientific public, being well convinced of the truth of Sir John Herschel's remark, that 'hasty generalization is the bane of science.' . . . I therefore fearlessly assert," writes Dr. Joule, in August, 1862, "my right to the position which has been generally accorded to me by my fellow-physicists, as having been the first to give decisive proof of the correctness of this theory."

Prof. Tyndall, although the English champion of Mayer's claims, did ample justice to his own countryman, as the following passage shows: "It is to Mr. Joule, of Manchester, that we are almost wholly indebted for the experimental treatment of this subject. With his mind firmly fixed on a principle, and undismayed by the coolness with which his first labors appear to have been received, he persisted for years in his attempts to prove the invariability of the relation between heat and ordinary mechanical force. He placed water in a suitable vessel, agitated it by paddles moved by measurable forces, and determined the elevation of temperature; he did the same with mercury and sperm-oil. He caused disks of cast-iron to rotate against each other, and measured the heat produced by their friction. He urged water through capillary tubes, and measured the heat thus generated. The results of his experiments leave no doubt upon the mind that, under all circumstances, the absolute amount of heat produced by a definite amount of mechanical force is fixed and invariable."

For this great scientific achievement the Royal Medal of the Royal Society was awarded to Mr. Joule in 1852; and eight years later, when men of science began more fully to apprehend the great value of the discovery, he was presented also with the Copley Medal of the Royal Society. On that occasion, Sir Edward Sabine, the president, alluding to the former award, used the following words: "Both awards refer to the same experiments, and are substantially for the same great step in natural philosophy. You are all aware that a great principle has been added to the sum of human knowledge—one fruitful in consequences in a thousand ways, and which, being accepted among undisputed truths, is now embodied, without question, alike in the most wide-ranging speculations and the most matter-of-fact practice. The award of two medals for the same researches is an exceedingly rare proceeding in our society, and rightly so. The council have, on this occasion, desired to mark by it, in the most emphatic matter, their sense of the special and original character and high desert of Mr. Joule's discovery. No words of mine could add to the value of the award."

Dr. Joule has figured but little in the fields of popular science, having only given a few lectures to the people in Manchester, and published no book, as we are aware, of any kind. But his contributions to scientific periodicals and the transactions of learned societies are very numerous, and give the results of prolonged and incessant original investigations, extending through many years. He became a Fellow of the Royal Society in 1850, received the degree of B. C. L. from Oxford, of LL. D. from the Universities both of Dublin and of Edinburgh, is a corresponding member of the Institute of France, and was President-elect of the British Association for the Advancement of Science, which met at Bradford last year.

EDITOR'S TABLE.

A FOREIGN LESSON AND A DOMESTIC APPLICATION.

THE celebrated Tichborne case, now closed in England, has one aspect which is as full of instruction for us as for the people among whom it occurred. The leading facts have been often printed, but, as the proceedings dragged through several years, it may be well to make a brief summary of the main facts involved in it. Roger Charles Tichborne was born in 1829, and was heir to a baronetcy and an immense English estate, yielding a revenue of $100,000 a year. His parents were an ill-assorted couple, of English origin and French connection, habitation, and language. The father is represented as weak, and the mother indolent, selfish, and willful. The family was Roman Catholic, and the boy passed through the hands of priests and tutors in Paris, and afterward attended school at Stonyhurst. He then entered the army, where he remained three years, when, tired of home, he resolved to travel, and, after visiting various ports in South America, disappeared, and is supposed to have been lost by the sinking of a ship at sea in the spring of 1854. His personality was peculiar and marked. Slender in *physique*, and with the manners of a gentleman, he had a half-French and half-English education, and "his examinations, his regiments, his barracks, his instructions, his drills, his peculiarities on parade, in the mess-room, or in quarters, his favorite novels, his amusements, his French songs, his topics of conversation, his associates, the cut of his clothes, the style of his boots, his whips, his fowling-pieces, his tobacco-pipes, his days of leave, his twitching, and his peculiar rendering of the words of command," were well known, and perfectly remembered by his associates. He was, besides, a copious letter-writer, and when in the New World kept a full journal, often copying it several times, and sending it home in the form of letters to his mother and aunt. "There was no change noticeable in him before leaving home, or any tendency to alteration of person, gait, or expression, nor any symptom that he was becoming less of a gentleman, or inclined to descend to a lower and freer social stratum."

The disappearance and supposed death of Roger placed his proud and willful and half-insane mother in an unpleasant position in regard to the estate, which would go to the child of a detested daughter-in-law. The disappointment became a possession, a frenzy, and she was determined not to endure it. She accordingly advertised in Australia for information regarding the missing heir of the Tichborne estate. It was a promising region in which to find one: as the London *Times* remarks. "A very large class there are more or less adventurous, taking the license and claiming the immunities of that character. Often changing employment and companionship, and filling up the gaps as they know best, they meet at stations, at diggings, at the bars of hotels, hearing and telling wild, disjointed, strangely-transmuted legends of that old home in the Northern Hemisphere, to them a wonder-land, a romance, and a tradition. It is always the strangest that travels the farthest, and what they do hear of the Old Country is just that which we regard as the least fair sample of it. They are also great novel-readers, and, while they read in shilling volumes numerous stories of patrimonies going a-begging, heirs lost and found, and clever men making their way to the palace from the dunghill,

they are also told that 'truth is stranger than fiction,' and, what is more, that audacity is sometimes found better than either." And so the desperate mother "had it published out there that there were good grounds for believing her son, the heir of a splendid patrimony, to have survived a wreck off the coast of South America, where he had been traveling, and to have possibly found his way to Australia, where, for reasons of his own, he might have changed his name, assumed a disguise, and adopted some common occupation."

The advertiser found her customer. There was an adventurer in Australia, Arthur Orton by name, although passing under another cognomen, a butcher and stock-driver, who had sailed about the Atlantic and Pacific, had visited the places where Roger Tichborne had been, had had various occupations, was a kind of Catholic, and an adept at duplicity. He announced himself as Sir Roger Tichborne, the sole survivor of the lost Bella, who was picked up and taken to Australia by another vessel, which with all its crew had quite vanished out of existence. The case would seem to have been unpromising. The claimant was a fat, clumsy, ignorant, low-bred vagabond, who did not understand a word of French, and could not write a note without twenty vulgar blunders, and for twelve months after he gave himself out as Sir Roger he was ludicrously in the dark as to every thing pertaining to the Tichborne family beyond a few stray facts which he had picked up from the newspapers—he did not know where the family property was situated, nor even his mother's name. It is said that at first he was hardly serious about his pretensions, but he was soon surrounded by plenty of those that were serious—attorneys, money-lenders, speculators, hangers-on of all kinds, stupid dupes and conscious accomplices, who backed him up, and urged him on in the enterprise of reclaiming the estate. Moreover, money was needed, and had to be advanced; and those who contributed it, although they may have doubted at first, doubted no longer.

Of course it will be said, a mother would know her own son, and the question of identification could be at once and very effectually settled. But she did not wait to see him before deciding the point. "As she had made up her mind, not only that her son lived, but also that he had lived for a long period among the scum of the human race, under false names and disguises, pursuing low occupations, and willfully forgetting all he was or had ever learned, her anticipations were only corroborated, and her faith strengthened by all she now heard of the man's figure, habits, language, writing, and associations." Every thing was encouraging, and seven years ago the claimant landed in England, and was at once recognized by the overjoyed mother as her long-lost son. The favoring circumstances and the tactics to which they gave rise are thus described by the *Times* writer:

"There was the infatuated mother, who at once handed over to her supposed son every letter, journal, and token of every kind, and all the information she could give toward the establishment—that is, the fabrication—of an identity. The claimant had also clever, and, of course, unscrupulous assistants, who saw at once what they had to do, and who did it. As the appearances were against him, they must not throw away a chance. What they had to do was to construct, by positive and particular evidence of the most minute and circumstantial kind, a fabric of identification so large that even if a good deal were knocked over, there would remain enough for the purpose, or, if not, enough at least to protract the war. Accordingly, all sorts of people were carefully hunted up, sounded as to their knowledge of the true Roger Tichborne, and their own recollections wound out of them. They were then plied with the evidence of others, and put upon the line of inquiry they were to take with the claimant. We think it may be said that every interview, not to say every meeting, of an apparently casual cast, was prearranged, and done by programme. Everybody was frankly told he would be rather startled at first, but at

the same time assured that the most competent witnesses had begun with incredulity and ended in full belief. There was a manufactory of affidavits ready to be submitted for the signature of all who had made even a partial surrender of their judgment. The man himself, it was always admitted, was indeed a prodigious development, so the comparison was always led away from the person to some minute or out-of-the-way circumstances, which it was said 'none but Roger Tichborne could possibly have known.' Few considered how completely the defenses had been opened to the claimant, and that he had the run of the Tichborne annals, archives, gossip, and every thing. Every day he had opportunities of acquiring a little more of the social gloss which befitted his assumed rank; every day his stock of information was added to; every fresh witness contributed some items; every day of both trials supplied new materials; every time a question was repeated, the claimant could answer it better than before, being better informed and better advised. Then he could always plead the tricks of memory, and was neither ashamed to have things brought to his remembrance nor to have forgotten what he had said the day before."

Of the stupendous trial which followed, the whole world is aware. Six years ago the claimant applied to the Court of Chancery as a first step to legal proceedings, and three years since he commenced a trial of ejectment in the court of Common Pleas, which lasted six months. Nine months ago he was himself put upon his trial for perjuries committed in the former case, and after 188 days' adjudication he was convicted by the jury in half an hour, as a perjured impostor. The solicitor-general occupied thirty-one days in opening the case, the counsel for defense consumed forty-seven days in summing up, and the chief-justice took eighteen days to deliver his charge, which would have filled 180 columns of the London *Times*. Half a million dollars were contributed by the English people, in the shape of bonds, to enable the claimant to prosecute the case, and, according to the *Spectator*, it cost to all parties—the crown, the Tichborne family, and the defendant's supporters—more than a million and a quarter of dollars!

Such are the leading features of the most extraordinary and the most celebrated lawsuit in all history, which has just come to an end. The question now arises how it became possible to get up so tremendous a struggle over so simple an issue. It might perplex us, far away as we are, to find a satisfactory answer, but the whole British press comes to our relief with a unanimity and an emphasis that are quite remarkable. They agree that the cause of so monstrous and overgrown a procedure is not to be ascribed to the defects of English law-practice, but to the gross ignorance, the silly love of the marvelous, the stupid credulity, and the wide-mouthed gullibility of the English people, who backed up the case and furnished the means for fighting it. The *Spectator* says: "The credulity which has been disclosed throughout the case is positively frightful. . . . Evidence of the most unanswerable character left the believers absolutely unmoved." And of the judge's charge it says: "Nothing but that slow-dripping, luminous narrative, with all its lengthy letters, and all its moral reflections, and all its apt quotations to justify its actions, would ever have fairly driven its illusions out of the British public." The *Saturday Review* says:

"Bishop Butler is reported to have once turned upon his secretary with the alarming inquiry, 'Why might not large bodies of men, and whole communities, be seized with fits of insanity as well as individuals?' The startled secretary could only suggest reliance upon Providence to avert such a calamity. It would certainly appear, however, that there are epidemics, if not of insanity, at least of infectious folly and unreasonableness, which come to pretty much the same thing. It is scarcely possible to account in any other way for such a deplorable exhibition of human silliness as has been afforded in connection with the Tichborne case. The really amazing thing about this imposture, as we look back on it, is, that it should ever have imposed on anybody. . . . An elastic credulity, however, can swallow any thing,

and the very difficulties of the claimant's case seemed only to strengthen the blind faith of his adherents. . . . It may be said that stupidity is a misfortune and not a fault; but there is a sort of cranky, cantankerous, pragmatical stupidity which sets itself up as superior to all plain and obvious considerations, and claims the gift of seeing through stone-walls, and of proving that two and two make four only for common folk, which is really an offense against decency and reason. There are people of this kind, who can bring themselves to believe any thing; and Arthur Orton may take his place by the side of the Cock-Lane ghost, the sea-serpent, and Mrs. Toft's litter of rabbits."

The London *Times*, referring to the dupes who were made witnesses, remarks:

"If they fell into an open trap, half England showed themselves ready to do the same. We are all now persuaded that the claimant is a low-born, illiterate, vulgar scoundrel, without any trace of education, either of schools or of society, with no lingering suggestion of culture of any kind about him. . . . It would have been quite impossible for this man Orton to have kept up his enterprise for a fortnight, if his way had not been made easy by a number of dupes of various ranks, which for weeks, and months, and even years, went on increasing. . . . We may now ask—and that is the point which most concerns us—how came this man, in spite of the most unfavorable appearances, to attract, to confirm, and to organize into a sort of faith, so vast an amount of human credulity? The answer must be that, in the first place, a large part of mankind, and that by no means of the lowest or least educated, wish to believe the improbable and prodigious. They are ready for any thing, because they really desire it. For this purpose, and in order that they may be more free to believe what they choose, they close their eyes to the most important and most material facts of the question, and their reasons to the great laws which should control a decision. They prefer to look about for the smaller particulars, the incidental circumstances, and some trifle or other, which may give them a key to the question. Vanity is satisfied, labor saved, and perplexity avoided, by an intuitive assent, resting upon something which, if not wholly inexplicable to other inquirers, is next to nothing at all in the scale of right reason. When people have no laws of judgment in themselves, little experience, or at least little fruit of it, no tests which they know how to apply, their faith, and with it their adhesion, is as much at the mercy of any one who practises upon it as a salmon is at the mercy of a dexterous angler. . . . It has been freely said, and will probably be often said again, that the length of time consumed before Arthur Orton has been convicted, as a perjured impostor, is a scandal upon our law. We cannot join in this opinion. Scandal there has been, undoubtedly, but the blame is misplaced when it is attributed to the administration of justice. The real ground of humiliation is the defect of common-sense, and the imperfect education of so large a proportion of the English people. If one thing more than another is and ought to be the object of training in schools, in colleges, and in daily life, it should be to enable a man of full years, and in the possession of ordinary faculties, to know what to believe, and what to disbelieve, to discriminate the value and the weight of evidence, to reject the false and to detect the true."

The British press, it is evident, has not failed to draw the proper lesson from this seven years' experiment upon the state of mind of that country. It is especially noteworthy that the folly which made it possible was not confined to the illiterate classes; the delusion carried away half the English people of all grades, and the result is no doubt correctly attributed to that general deficiency in educational methods which neglects the proper study of evidence.

And from this point of view the Tichborne case is not without interest to us; for we have an education similar to the English in that it does not enforce the critical study of proof, and therefore leaves the people without protection against the tactics of ingenious imposture. That impositions of all kinds should arise under such circumstances is natural. We may not be able to exhibit any such stunning example of audacious imposture as our English friends have just exploited, but we have plenty of the same kind of thing on a smaller scale. Whether deception and fraud are more extensive here than elsewhere, or more extensive now than

formerly, we do not inquire; but their extent is certainly alarming. It would almost seem that overreaching, and circumventing, and the attainment of ends by false pretenses, are becoming organized in our blood, for "smartness" and "sharpness" have acquired new meanings and are openly commended, and nothing is more common than the remark that a little humbug is indispensable in all successful management. Certain it is that we are duped and cheated continually, and in a thousand ways. At home and on the street, in the cars, at public assemblies, and in all the relations of life, we are beset and imposed upon by designing knaves of every shade. We eat the falsified foods of the grocer, and wear the swindling textures of the dry-goods man. We are "done" by unscrupulous shoemakers, and "sold" by dishonest hatters, while builders construct for us fraudulent houses, and upholsterers fill them with sham furniture. The gas-men and the street-cleaners sell us one thing and furnish another, and, turn where we will, we are plied with plausible deceptions, and made the victims of ingenious rascality. Granting that much of this is inevitable, it is certain that more of it might be avoided, and is due to that credulous state of mind by which, like fools, we believe half that is told us.

If, leaving the sphere of private dealings, we take a wider outlook, the case is far from being mended. Under our republican institutions politics is a universal interest and a semi-occupation of everybody, and who does not know that it is given over to interminable deception and the rankest fraud? An unscrupulous demagogism overshadows the land and shoots down its multitudinous roots into the same stupid public credulity. What else are our political parties but contrivances for massing, organizing, and manipulating, the gullibility of the people? Year after year they are fooled by crafty intriguers, and no braying in the legislative mortar is sufficient to drive their foolishness out. The patriotic perfection of the partisan is measured by his swallow; he must gulp every thing that is administered from his own side, and his steady and stupid faith is the stock-in-trade of political gamesters. A motley crowd of those who have outdone their rivals in the unscrupulous tactics of the canvass get together in some grand edifice, which from corner-stone to liberty-cap is a monument of fraudulent jobbing, and they then call themselves a "government," while the superstitious multitude hails the conclave as the "assembled wisdom." Wise in all the arts by which a credulous people are deluded they certainly are; for how else would their lying promises continue to pass from hand to hand as veritable money?

Now, against all this multifarious imposture, this liability to be misled by calculating knaves of every complexion, what is our defense? How much is accomplished by the 300 colleges, and 800 academies, and altogether some 2,000 high-schools, supplemented by 168,000 common schools, in the way of guarding the people against the delusions and deceptions to which they are perpetually exposed? The common schools bring the mass of them up to the point of reading the newspapers, and thus greatly increase their exposure, but they furnish no mental resources of counteraction. The newspaper has its useful office, but it is the most efficient instrument of a vicious partisanship, and an instrument easily wielded by designing men. The higher institutions turn out the raw material which is quickly worked up into knavish managers on the one hand, and credulous partisan gulls on the other; for, as Mr. Carlyle remarks, "quack and dupe are at bottom the same thing." We find the cause of this wide-spread evil, as the *Times* remarks, in a faulty mental training which gives the culti-

vated man but little advantage over the illiterate one. It is questionable, indeed, if the common sense of untaught people is not to-day quite as good a defense against preposterous pretensions, and the arts of skillful deception, as the elaborate cultivation of the schools. It is true that logic, as the art and analysis of reasoning, is more or less taught, but it is taught to but little practical purpose. Learning the rules of logic may assist to make a dexterous intellectual fencer, but it will no more make a circumspect and cautious thinker than learning the rules of morality will make a virtuous man. The darkest period of human credulity, when no extravagance was too gross to be greedily swallowed, was the golden era of the study of logic in all the schools of Europe.

It is often said that we are indebted to modern science for the emancipation of the human mind, but it is frequently forgotten in what its slavery consisted, and how science proceeded to set it free. The mental thraldom of the dark ages consisted in the submission of the mind to beliefs imposed on it by authority, and interpreted by authority; the effect of which was to make blind credence the universal mental habit. The influence of theology was by no means confined to religious opinions. Men accepted their views of Nature on the authority of Aristotle as much as their creeds on the authority of the Fathers. Holding it sinful to disbelieve, they avoided the sin in all things. Modern Science began by attacking this state of mind, and has won her great conquests on the principle of the supremacy of personal observation as against the weight of traditional belief. But there must be doubt of authority before there can be rebellion against it. The first step toward truth, or the verification of opinions, is therefore a skeptical state of mind in regard to what has hitherto passed as truth. The great poet missed the philosophy of the case when he said:

> "Truth can never be confirmed enough,
> Though doubts did ever sleep;"

for the slumber of doubt is not favorable to the confirmation of truth. There is but one thing that can protect people against the thousand-fold insidious and plausible impostures to which they are continually and everywhere exposed, and that is a resolute mood of skepticism, and an intelligent habit of sifting evidence that shall become a daily and constant practice. Our education is here seriously at fault. It neither provides for the requisite discipline, nor does it insist upon its necessity. The old universities were originally religious seminaries, and all teaching was at first in the hands of the clerical profession; while even yet our presidents of colleges are mainly doctors of divinity. The world owes much to the clergy as the conservators of learning in the past, and the teachers of mankind when there were no others to perform the office; but their service in this respect has not been an unmingled good: it has had its drawbacks which still survive. To this day there is an almost universal feeling that belief and disbelief answer to each other as virtue and vice. The very terms which indicate the state of mind preparatory to all rigorous investigation of truth are tainted with prejudice and held to involve an implication of criminality. With such a bias it is most difficult to train the mind to that healthy habit of doubt which shall give it protection against the thousand-fold impostures which assail it on every side.

Perhaps the evil here considered can never be wholly eradicated from society, but much can be done to diminish it, and it is the proper office of education to do it. And as science by its mental method has put an end to the grosser forms of credulous belief and blind superstition, so when that method is carried into general education we may expect still further advantages of the same kind. Scientific education, truly

such—not the mere committal and recitation of text-books, but a practical and systematic exercise of the mind in observation, inference, judgment, and the weighing of evidence—will meet the present requirement as nothing else can. Much may be done by the diffusion of scientific knowledge to dispel the ignorance which is taken advantage of by practised charlatans; but people cannot learn every thing, and there are many things of which the most intelligent must remain ignorant. There ought, however, to be no difficulty in learning how to deal with the claims and pretensions that are put forward, even though the facts involved are not understood; and this is simply a question of the criteria of truth and of cautious habits in accepting proof.

THE PROGRESS OF THEOLOGY.

In our office as chroniclers of the progress of scientific thought, we are called upon to record some further and marked concessions to the position that the doctrine of Evolution is not an anti-religious doctrine. For the last fifteen or twenty years since this theory has been definitely enunciated, and sustained on scientific grounds, there has been vehement protest, on the part of many theologians, that it negatives all possibility of religion. The leaders have not hesitated to make up the issue between religious belief and a doctrine of science which simply depends upon accumulated evidence. The view supposed to be so fraught with danger has, however, been steadily making its way in the minds of those most competent to judge of its truth; and now it is beginning to be perceived that the alarm was groundless, and that, though Evolution be established, the great questions of theology remain just where they were before. A favorite position has been that the conception of Evolution is inconsistent with the idea of Divine design in Nature, but it is now acknowledged that the only effect is to substitute a larger for a narrower view of design. Dr. McCosh, in his lectures, a year or two since, put the question on this broad ground. He said, virtually, "Establish whatever facts you please in regard to the workings of Nature and the order of the universe, and behind the whole phenomenal scheme I find the Infinite mind by which it was all designed." A new and very able work has just appeared, entitled "Darwinism and Design; or, Creation by Evolution," by Mr. George St. Clair, F. G. S., in which the whole problem is elaborately discussed from the new point of view. The author takes the same ground as Dr. McCosh, and argues ably against those who hold that Evolution is destructive of teleology, or the doctrine of ends and purposes in Nature. He admits that it is inconsistent with the old restricted interpretations of teleology, but claims that it only substitutes a far more comprehensive principle of the same kind. We note that the *Nonconformist*, the organ of the English Dissenters, and one of the stanchest orthodox periodicals, gives in its adhesion to Mr. St. Clair's positions, and highly commends his work. An article in our present number gives the argument upon this subject of Prof. Jevons, the able English logician, to the same purport, and also the substance of an address by a distinguished divine of New York, illustrating similar views. The present aspect of the case thus becomes interesting. It looks as if theology itself were about to take a great advancing step, which it has stoutly resisted, but has been at length compelled to take by the advance of scientific research. After a few more such experiences it is to be hoped that our friends will begin to recognize that theology is also progressive, and that, so far from being an enemy, Science is a helping friend of true religion.

LITERARY NOTICES.

PRINCIPLES OF MENTAL PHYSIOLOGY: With their Applications to the Training and Discipline of the Mind, and the Study of its Morbid Conditions. By WILLIAM B. CARPENTER, M. D., LL. D. New York: D. Appleton & Co. 737 pages. Price, $3.00.

As this work was announced to appear in the "International Scientific Series," and has been withdrawn from it, a word of explanation is here desirable. In drawing up the plan of this series, it was decided that one of the books now most called for is a compendious treatise upon the science of man, based upon the intimate interactions of body and mind, or what may be termed Mental Physiology. While Prof. Bain took up the theories of their relation as a philosophical question, there was wanted a practical exposition of the science of Human Nature, such as might become a text-book of guidance and education in the general conduct of life. Dr. Carpenter, whose numerous and well-known physiological works covered this ground more perfectly than those of any other author, was applied to as the most competent man to prepare the work required. When solicited to undertake it, although much occupied with his active duties as Registrar of the London University, and absorbed in a course of special scientific inquiries, he cordially consented, and at once entered upon the labor. But it soon became apparent that the subject was too large to be compressed within the limits which were thought advisable for such a series, and, rather than impair the value of so important a work, it was found best to take it from the list and issue it separately. It conforms, however, to the popular style of these works, and is well adapted for general reading.

Dr. Carpenter's work is neither a technical treatise upon physiology nor a manual of scientific psychology, but it is an elaborate exposition of those relations of body and mind which must form a foundation of any true science of human nature. Physiology is generally considered as a science that belongs to the doctors, and of which it is necessary for everybody to know something for hygienic reasons. But the study of man, for general practical purposes, has hitherto been held to consist in the study of mind, while that has been considered from the metaphysical point of view, the body being thrown out of the account. This has been the powerful tendency of the past, and it is still so influential that books upon the so-called science of man are still frequently issued which are limited to one portion of his nature, and that, too, studied by a false method and out of all its actual relations. This disruption of man and the contemptuous dismissal of one part of his being as his "lower nature," while the other is magnified and dealt with apart, has been formerly defended on religious grounds; and the attempt to bring his whole nature into view and to consider it in its wonderful unity has been resisted as involving "materialism." This view is, however, latterly giving way, and it is more and more recognized that man must be studied in the totality and living harmony of his nature. Dr. Carpenter quotes the impressive words of Charles Buxton in his "Notes of Thought," as indicating the point of view that must now be taken in relation to this subject. Mr. Buxton says: "Irresistible, undeniable facts demonstrate that man is not a den wherein two enemies are chained together, but *one being*—that soul and body are one—one and indivisible. We had better face this great fact. 'Tis no good to blink it. Our knowledge of physiology has come to a point where the old idea of man's constitution must be thrown aside. To struggle against the overwhelming force of science under the notion of shielding religion is mere folly."

Dr. Carpenter adds: "These well-considered conclusions of a deeply religious mind may be specially commended to the consideration of those who are disposed to condemn without examination any thing that savors of 'materialism' which they have been accustomed to regard as philosophically absurd and morally detestable. And those who assume that physiological psychology strikes at the root of morals and religion may be fearlessly asked to show in what a system which leaves the will of man free to make the best use he can of the intellectual and moral capacities with which his bodily organism has been endowed by his Creator, and which gives him the strongest and no-

blest motives, both for self-discipline and for philanthropic exertion, is unworthy of the nature and destiny of the being whose creation in the 'image of God' can have no higher meaning than his capacity for *infinite progress*."

The difference between the new point of view and the old is not a mere speculative difference, or a matter of abstract belief. The study of man as an actual whole, a complex working phenomenon, and a fact of experience, has given us a kind of knowledge that is invaluable for the uses of all in every-day life. This kind of knowledge, concerning human nature, has been long and slowly accumulating, as the result of modern observation, though it has recently become more extended and accurate in many particulars, and Dr. Carpenter's work, we may say, has first presented it with the systematic fullness which its importance demands.

In his plan of treatment, Dr. Carpenter classifies from the mental side; that is, it is mental phenomena and problems that are successively taken up. After a preliminary statement of the general relations between mind and body, in the first chapter, he takes up the structure and modes of action of the nervous apparatus in the second chapter, and then proceeds to consider in successive chapters the subjects of Attention, Sensation, Perception, and Instinct, the Emotions, the Will, Memory, Common-sense, Unconscious Cerebration, Reverie, Sleep, Dreaming, Somnambulism, Electro-biology, Mesmerism, and Spiritualism, Intoxication and Delirium. But each and all of these manifestations are considered, not in themselves merely, but as conditioned by the physiological constitution. Whatever may be their ultimate nature, practically they are effects of a vital mechanism by the laws of which they are determined. Much of this wonderful connection is of course, as yet, far from being understood. We are indebted to Dr. Carpenter for having shown that a great deal more is understood of the psychical and vital interactions than has become generally known. Dr. Carpenter has won his reputation as a physiologist, largely from the clearness of his expositions, and the present work shows that his capacity in this respect is still vigorous. Its most scientific parts are attractive reading, and the extensive array of personal instances and incidents, which illustrate his positions, gives great fascination to the volume. It is a book hard to lay down when once entered upon, and Dr. Carpenter may be congratulated upon having contributed so fresh and adequate a book upon such an important subject.

THE PRINCIPLES OF SCIENCE. A Treatise on Logic and Scientific Method. By W. STANLEY JEVONS, M. A., F. R. S., Fellow of University College, London; Professor of Logic and Political Economy in the Owens College, Manchester. New York: Macmillan & Co. 2 vols., 943 pages. Price, $9.

THIS able treatise is entitled to be classed at once with such valuable and solid works as Mill's "Logic," Whewell's "History of the Inductive Sciences," and Herbert Spencer's "First Principles." Whether it be equal to either of those treatises, as a contribution to scientific knowledge, we shall not assume to say, but it is certainly a timely and powerful exposition of scientific method, in the light of the later advances of knowledge. The author sets out with the assumption, which few will question, that the rapid progress of the physical sciences during the last three centuries has not been accompanied by a corresponding advance in the theory of reasoning. Physicists are usually too much engrossed in the immense and ever-accumulating details of their special sciences to give sufficient attention to the methods of reasoning which they unconsciously employ. It becomes necessary, then, that certain minds should devote themselves absorbingly to this neglected side of science, for few will deny that the clearing up of questions of order, logic, and method, are indispensable to its rational progress. To do any justice to this work, by a notice or review of it within such space as we can allow, would be impossible, and the best course is to let the author speak for himself in regard to the aims and characteristics of his undertaking. The following passages are from his preface:

"The study both of Formal Logic and of the Theory of Probabilities has led me to adopt the opinion that there is no such thing as a distinct method of induction as

contrasted with deduction, but that induction is simply an inverse employment of deduction. Within the last century a reaction has been setting in against the purely empirical procedure of Francis Bacon, and physicists have learned to advocate the use of hypotheses. I take the extreme view of holding that Francis Bacon, although he correctly insisted upon constant reference to experience, had no correct notions as to the logical method by which, from particular facts, we educe laws of Nature. I endeavor to show that hypothetical anticipation of Nature is an essential part of inductive inquiry, and that it is the Newtonian method of deductive reasoning, combined with elaborate experimental verification, which has led to all the great triumphs of scientific research.

"In attempting to give an explanation of this view of scientific method, I have first to show that the sciences of number and quantity repose upon and spring from the simpler and more general science of logic. The theory of probability, which enables us to estimate and calculate quantities of knowledge, is then described, and especial attention is drawn to the inverse method of probabilities, which involves, as I conceive, the true principle of inductive procedure. No inductive conclusions are more than probable, and I adopt the opinion that the theory of probability is an essential part of logical method, so that the logical value of every inductive result must be determined consciously or unconsciously, according to the principles of the inverse method of probability.

"The phenomena of Nature are commonly manifested in quantities of time, space, force, energy, etc.; and the observation, measurement, and analysis of the various quantitative conditions or results involved, even in a simple experiment, demand much employment of systematic procedure. I devote a book, therefore, to a simple and general description of the devices by which exact measurement is effected, errors eliminated, a probable mean result obtained, and the probable error of that mean ascertained. I then proceed to the principal, and probably the most interesting, subject of the book, illustrating successively the conditions and precautions requisite for accurate observation, for successful experiment, and for the sure detection of the quantitative laws of Nature. As it is impossible to comprehend aright the value of quantitative laws without constantly bearing in mind the degree of quantitative approximation to the truth probably attained, I have devoted a special chapter to the theory of approximation, and, however imperfectly I may have treated this subject, I must look upon it as a very essential part of a work on scientific method.

"It then remains to illustrate the sound use of hypothesis, to distinguish between the portions of knowledge which we owe to empirical observation, to accidental discovery, or to scientific prediction. Interesting questions arise concerning the accordance of quantitative theories and experiments, and I point out how the successive verification of an hypothesis by distinct methods of experiment yields conclusions approximating to but never attaining certainty. Additional illustrations of the general procedure of inductive investigations are given in a chapter on the 'Character of the Experimentalist,' in which I endeavor to show, moreover, that the inverse use of deduction was really the logical method of such great masters of experimental inquiry as Newton, Huyghens, and Faraday.

"The application of scientific method cannot be restricted to the sphere of lifeless objects. We must sooner or later have strict sciences of those Mental and Social phenomena which, if comparison be possible, are of more interest to us than purely material phenomena. But it is the proper course of reasoning to proceed from the known to the unknown—from the evident to the obscure—from the material and palpable to the subtile and refined. The physical sciences may therefore be properly made the practice-ground of the reasoning powers, because they furnish us with a great body of precise and successful investigations."

It is thus evident that the plan of Prof. Jevons's work involves a thorough handling of the most recent questions that have been raised in science and philosophy, and an examination of it will show that he has carried out his project in an able and independent manner. We publish a portion of his

last chapter, showing his liberality of view. It is to be hoped that the publishers will find it for their interest to modify the price of this work, so as to bring it within reach of a large circle of those who, in our opinion, would be glad to have it.

POLITICS AND MYSTERIES OF LIFE INSURANCE. By ELIZUR WRIGHT. Boston: Lee & Shepard. 238 pp., 12mo. Price, $1.50.

THE object of this work is to call public attention to certain practices in the existing system of life insurance, entailing loss and injury upon the policy-holder. Chief among these practices is the treatment of holders who allow their policies to lapse by non-payment of the premium, or surrender them from a desire to change the investment. In either case it is usual for the company to issue a "paid-up policy," that is, a guarantee to pay a fraction of the original policy at the expiration of its term, or to pay the resigning policy-holder a small sum of money as the "surrender value" of the policy. Mr. Wright assumes, and it must be confessed with great show of reason, that the "surrender value," in all cases where the policy has existed beyond three years, and in some cases beyond one year, is far less than the amount the policy-holder is justly entitled to receive. According to his idea, legitimate life insurance is a compound of insurance proper with the savings-bank business, and his system is therefore termed Savings-Bank Life Insurance. From this point of view all premiums paid are resolvable into two parts. One part pays the cost of insurance, that is, the expenses of the company: the other is merely a deposit, in trust with the company, for gradual accumulation to equal the sum of the policy by the time that that shall become due. Either part may be larger or smaller, according to the nature of the policy. With "ordinary life" policies, the premiums are small, and distributed over a great number of years; there is, therefore, great risk that the company will have to pay the policy before the accumulated deposits can yield a sum to equal it. To compensate it for this great risk, the company is justified in taking for itself the largest part of the premium. But, in the case of an endowment policy of short term, the premium being large and confined within a few years, the deposit accumulates very rapidly, and will soon equal the policy. There being, therefore, much less risk than in the former case, the company can be justified in taking only a small part of the premium for its own use. Thus it is plain that the company's share of the premium is largest in the case of an ordinary life policy, and smallest in that of a short-term endowment policy. It is called the "insurance value," and is appropriated to the payment of the expenses of the company. The policy-holder's share of the premium is smallest with the first kind of policy and largest with the last; it is called the "reserve," and should never be touched for any other purpose than the payment of the policy to which it belongs. Mr. Wright contends that the policy-holder should be at liberty to return his policy at any time, and withdraw the "reserve" unimpaired, save in a small sum to compensate the company for the loss of a good risk. In some cases the policy-holder is entitled to recover more than the "reserve" when he surrenders his policy. This occurs with "single-premium policies"—policies on which many future small premiums are anticipated, or commuted by the payment of a single large premium. This single large premium, like the small annual premiums considered above, resolves into two parts, the "insurance value" and the "reserve." The "reserve" is the same in nature as with the annual premium, though of course much larger; but a new element enters into the composition of the "insurance value." The "insurance value" of an annual premium compensates the company for its risk in one year, while the "insurance value" of a "single premium" compensates the company for its risk during all the years that the policy has to run. Now, if the holder of a "single-premium policy," having twenty or more years to run, becomes desirous to surrender his policy at the end of five years, he should get back from the company, not only the "reserve," but also that portion of the "insurance value" that has been set apart by the company to compensate for the risk attached to the remaining fifteen or more years of the policy's term.

Clearly, if the company retains more of the "insurance value" than will compensate it for bearing the risk during the five years that have expired, it will exact pay for work that it has not performed, and its proceeding cannot be justified on any ground of equity. The company is, of course, entitled to some compensation for the loss of its interest in the "insurance value" that it would have earned had the policy remained in force; but it is idle, as well as inequitable, to contend that the compensation should equal the "insurance value." It seems to us that the present value of the unearned "insurance value" would be the just compensation. Mr. Wright, however, argues that it should be only enough to enable the company to procure as good a risk as the one it has lost by the surrender of the policy, and that eight per cent. of the unearned "insurance value" would be sufficient for this purpose; that is, eight per cent. would yield an amount equal to the commission usually paid to an agent to obtain a risk. Mr. Wright, it is seen, holds that loss of the risk is that for which the company should be compensated, but to us it seems to be, as above expressed, loss of interest in the "insurance value" which would have been paid to it had the policy remained in force. This "insurance value" on the company's share of the premiums is supposed to compensate the company for the risk of undertaking to carry the policy, and is clearly the only interest that the company has in the transaction. The compensation that the company receives in case of surrender is called the "insurance charge." As it is based on the "insurance value" it varies proportionately, and is therefore largest on "ordinary life policies" and smallest on "short-term endowments," and on the latter class of policies it decreases as the age of the policy increases. To recapitulate, Mr. Wright contends that life insurance is compounded of insurance proper and the business of the savings-bank; that the premiums consist of two parts, the "insurance value," which belongs to the company when earned, and the "reserve," which belongs to the policy-holder, having been merely deposited with the company for accumulation, to be withdrawn whenever it suits him to return his policy; that the company for its interest in the risk is entitled to make a "surrender charge" when the policy is returned; and that this "surrender charge" should be based on the "insurance value," but should constitute only a very small part of it. This is, without doubt, a just conception of the nature of life insurance; but, while the companies agree with Mr. Wright in dividing the premiums into "insurance value" and "reserve," they disagree with him as to the ownership of the "reserve," half of which they insist on retaining for themselves, in case of surrender. The Mutual Life, of New York, retains from fifty to seventy-five per cent. of the "reserve," in settling for surrendered policies, and the Equitable from fifty to sixty per cent., and this is done on all policies alike, without respect to age or class. Having just seen that the "surrender value," usually constituting the difference between the "reserve" and a moderate "surrender charge," and sometimes exceeding the "reserve," varies in amount with the class of the policy, and far more so with its age, the reader is competent to decide for himself whether the company's uniform practice of retaining from fifty to seventy-five per cent. of the "reserve" on all policies is or is not equitable. For our part we think, with Mr. Wright, that it is not.

Mr. Wright further contends that both the "surrender charge" and the "surrender value," at any period of the policy's existence, should be ascertained sums, and known to the policy-holder before he insures, so that he can understand all the terms of the contract he is making. For this purpose he has prepared, and inserted in the book, several specimen-tables showing the "insurance value," the "reserve," the "surrender charge," and the "surrender value" of various classes of policies at the time of issue and in each year thereafter. This is precisely what the companies claim cannot be done. They say that the "surrender value" at any future time cannot be calculated, because it is impossible to foretell what the dividends or surplus above working cost will be. But, throwing dividends out of the question as an unessential factor, the thing becomes easy enough. For instance, no company will

deny that the "reserve" at any period of the policy's existence can be easily ascertained. But the "reserve" is made up of one part of the premiums, and, if this part can be ascertained, why cannot the "insurance value," which is made up of the other part of the premiums, be also ascertained? It is unnecessary to know any other factors than these, to be able to determine the amount of the "surrender value." The latter factor forms the basis of the "surrender charge," which may be eight per cent. of it, and the "surrender charge" deducted from the former leaves the "surrender value."

We have thus endeavored to give a brief outline of the main feature of Mr. Wright's book; the others are chiefly incidental to the illustration of this one. The glimpses occasionally given of the manner in which matters are conducted beneath the surface of life insurance are not calculated to leave on the reader's mind a favorable impression of at least one or two of the actors. In this connection, however, the tone of the writer is not always as dignified as it might be. The chapter at the end of the book, on the relation between currency and life insurance, exhibits some sound financial views. The book aims a vigorous blow in defense of the people, and it is to be hoped that its effect will be decisive.

CONTRIBUTIONS TO SOLAR PHYSICS. By J. NORMAN LOCKYER, F. R. S. New York: Macmillan & Co. 1874. 676 pages. Price, $10.

THE avidity of the general public for information in regard to recent researches in physics, and particularly in regard to researches made by aid of the spectroscope, is witnessed by the number of volumes which have appeared within the past few years devoted solely to the popular exposition of these subjects. The announcement of a new book with the same purpose is one which, we should fancy, the average reader of these books would receive with mingled feelings. It seems to us that this average reader, while feeling that it was his duty to rejoice that the class which he represents was being so very fully supplied with treatises on a certain class of topics, would likewise begin to doubt whether the topics themselves had not been exhausted.

At least, he might doubt whether the popular exposition of them had not been carried to an extreme point. Certainly it seems very hard to add to the books of Roscoe and Schellen any thing in regard to the fundamentals of Spectrum Analysis, which shall be worth adding. It is easy to conceive our average reader turning the pages of a new book of this sort with a kind of nervous fear, lest he should come across those tiresome wood-cuts of a German-looking man gazing intently into a prism in the hope of seeing a candle-flame double, or of two sombre individuals shut up in a dark and very large room, alone with Newton's experiment. These wood-cuts he has seen for years, and they seem to him as the brown-stone houses on the Fifth Avenue seem to the weary traveler; mile-stones that he can never pass—"a procession which never gets past its given point."

Now, we distinctly sympathize with our average reader, and we claim that a book of this nature, to be necessary or even acceptable at this time, must be a decided step in advance of the former ones.

The volume before us contains 676 pages (including a good Index), and it is divided into two parts: Part I. is devoted to a popular account of ancient and modern Sun-work; Part II. contains communications made by the author to the Royal Society of London, and to the French Academy of Sciences. Added to these we have sixteen valuable Notes on various special points; and two Appendices, one giving the "Instructions to Observers of the Eclipse of 1871," and the other being Respighi's "Memoir on Solar Prominences."

To consider the volume in inverse order, we may say that, of Part II., the valuable Notes and Appendices are the only parts which ought to have been given in their present form, according to our judgment, and it may even be doubted whether the Notes should not have been worked into the text. Mr. Lockyer says, in regard to the contributions to the Royal Society and to the Academy of Sciences, that they are "of course" given *verbatim*. Here the author has, it seems to us, forgotten the

proper object of his book. These papers were written from time to time as results began to come from the "new method," and they are of necessity incomplete. The only object in giving them in their original form is to show exactly Mr. Lockyer's relation to the progress of discovery and research. But the history of the subject is very well known among all interested in it, and Mr. Lockyer's foremost place in certain branches of it is too well established to need a repetition of the formal proofs.

To the scientific worker these papers are already accessible in the original, and, for general purposes, they should have been entirely recast, as they are decidedly not in the best form now.

With regard to the first part of the work we may say that much of it is a repetition of matter which has been thoroughly treated in other books. Some of it consists of accounts of eclipse-work which the author himself did, and the story of this is told in a thoroughly good and interesting way. Mr. Lockyer's accounts of the work of others are eminently fair, and exhibit good feeling and entire appreciation. The chapter on Mr. Carrington's researches on solar spots is an example, and the author's account of the discovery of the new method of viewing prominences which was applied by Janssen and himself, though first conceived by Lockyer, is thoroughly admirable for fairness and candor.

Part I., however, has more serious defects than the final section of the book. It is entirely deficient in judicious arrangement, and its perusal can only confuse the ideas of the learner. It is, in fact, a reprint of essays (each of them good in itself and in its place), which Mr. Lockyer, sometimes alone, sometimes in concert with Mr. Balfour Stewart, contributed to English periodicals, and of occasional lectures.

It abounds in repetitions; sometimes whole paragraphs, almost pages, are printed at least twice, and the whole seems to show a desire, to speak plainly, to "make a book."

We must insist that, while it is, abstractly, a thing to be grateful for that Mr. Lockyer should give his valuable time to the popular exposition of scientific truths, some of which he has been so fortunate as to discover, it is, in the case before us, still a fact that he has added scarcely any thing to the ample information in regard to them which is now accessible, and nothing at all to his scientific reputation.

His character as a man seems to be shown, in his account of his relation to other scientific men—his friends—and that is almost the only outcome of this expensive volume, whose principal fault is a want of a sufficient *raison d'être*.

THE MARTYRDOM OF MAN. By WINWOOD READE. New York: Asa K. Butts & Co. 543 pp. Price, $3.00.

THE reader of this book is long puzzled to discover the fitness of the title to the matter presented for his consideration, nor can he, until, near the end, the author's view is revealed to him, that each generation of mankind, from the conditions of its existence, is subjected to physical persecution —or martyrdom—that the condition of the succeeding generation may be improved. The current theology is repudiated, and with it the idea of the individual existence of the human soul after death. The idea of a God, impersonal, indefinable, and unknowable, is, however, retained and strongly enforced; and with it there seems to be connected in the author's mind, though it is not clearly expressed, an idea that the human soul is immortal in the sense of being a materially embodied part of the great animating power of the universe, into which it lapses—losing its individuality—after the death of the body. To expound these views is really the aim of the book, although it ostensibly purports to be a kind of universal history of human progress, written to show the influence of Africa upon civilization. It is divided into four chapters. The first presents a panoramic portrayal of the ancient civilizations of Egypt and the north of Africa, Asia Minor, Greece, Rome, their rise, maturity, and decay, and the influence they exercised upon each other. The second chapter deals, after the same manner, with mythology, Judaism, Christianity, Mohammedanism. The third traces the progress of Liberty, giving a comparatively extended account of the origin of the slave-trade and the antislavery movement, and their influence upon American affairs.

The last chapter sketches the rise and progress of intellect, and pictures its probable future. The theories of evolution and natural selection form the ground-work of the plan. The author acknowledges his indebtedness to others for his facts, but is entitled to some credit for originality in the conception and arrangement of the work. The style is vigorous, and entices the reader into more than a cursory perusal.

THE STRUCTURE OF ANIMAL LIFE. By LOUIS AGASSIZ. New York: Scribner, Armstrong & Co. 128 pages, 8vo. Price, $1.50.

THIS book comprises a series of six lectures, delivered in 1862, before the Brooklyn Institute, and first published in 1865, but now reissued, the former editions having passed out of print. The lectures were delivered for the purpose of showing that there is "order in Nature; that the animal kingdom, especially, has been constructed upon a plan which presupposes the existence of an intelligent being as its author," and the "scientific grounds of the working of a Providence in the world." In the last respect, the view advanced is that the present diversity of animal life, or species, has not resulted from the influence of outward circumstances upon a few primarily simple forms, but from the direct and continually-repeated workings of a Divine Will or Providence; in other words, that the diversity has resulted from Divine creations. The arguments adduced to prove this part of the theory are grounded upon the fact that geologic revelations show certain low forms of animal life to have existed in former periods, in greater diversity than at present. The first lecture presents the plan of the animal kingdom as exhibited in its four great divisions; the second presents the relative standing of each division to the other, and of the various members of each division; the third proves the antiquity of animal life by the existence of coral-reefs; the fourth gives an outline of the geological history of the earth. The remaining two lectures are devoted to proving the theory of an intervening Providence. The book is full of interesting facts, and eminently adapted to the theology of the day.

PRESENT STATUS OF SOCIAL SCIENCE: A Review, Historical and Critical, of the Progress of Thought in Social Philosophy. By ROBERT S. HAMILTON. New York: H. S. Hinton, 744 Broadway. 332 pages. Price, $2.00.

A WELL-EXECUTED book, upon the subject here designated, would be very valuable: the present one seems to be not up to the requirement. Upon a class of questions which, of all others at present agitating the scientific world, are the freshest and the newest, this is an old book. It was prepared for publication seven years ago, and was not even then up to the times. An example of the antiquated and unreliable character of the work is afforded by the author's treatment of the most eminent thinker of the time on problems of social science. Mr. Herbert Spencer is judged as a sociologist by his views developed in "Social Statics;" how fairly will appear from the fact that "Social Statics" was Mr. Spencer's first work, published twenty-four years ago. And not only this, but he was himself so dissatisfied with it that he would not consent to its republication in this country, without incorporating a preface which indicated that his views had undergone important modification. It was, in fact, from the incompleteness of the basis of this discussion for a true sociological science that Mr. Spencer was led to devote himself for twenty years to the development of a system in which the foundations of sociology should be more deeply and securely laid in the sciences of life and mind, and the laws of Nature, in their latest and highest interpretations.

Mr. Hamilton's book ranges wide over the field of social philosophy, and discusses the views of many men in relation to it, but, with much information, there is a vague speculation, and more of criticism than history. Of social science, as a simple generalization of social phenomena, or a body of principles based upon facts of observation, like other sciences, he seems to have but an obscure conception, as is evinced by the following statement of the problems of social philosophy: "What are the causes or laws which determine the social destiny of the individual, which determine in the long-run, and in the absence of extraordinary disturbing causes, whether he shall be prosperous or the contrary; whether he shall

be a pauper or millionaire; a laborer or capitalist; a peasant or prince—which determine, in short, whether his own internal momentum or *centrifugal* force shall be overpowered by the potent gravitation, or *centripetal* force, which is constantly prostrating human efforts, or shall enable him to maintain an independent position, and REVOLVE IN AN ORBIT OF HIS OWN."

A TREATISE ON THE METHOD OF GOVERNMENT SURVEYING. By SHOBAL V. CLEVENGER, U. S. Deputy Surveyor. New York: D. Van Nostrand. 200 pp., 12mo.

THE author states that the peculiarities of Government surveying being unexplained by existing works on land-surveying, new contractors with the Government are often embarrassed by the want of information on the subject. To meet this want, the treatise was prepared. The principles of surveying, the application of astronomy, and the uses of instruments and of logarithmic tables, are expounded briefly but intelligibly. Suggestions are also made for procuring a surveying outfit, and for rendering the alkaline waters of the Western Plains fit for drinking. Tables of convergences, logarithms, etc., are given at the end. The book is bound in morocco for pocket-use.

THE BORDERLAND OF SCIENCE. By RICHARD A. PROCTOR, B. A. Philadelphia: J. B. Lippincott & Co. 438 pp., 8vo. Price, $4.00.

THIS is an embodiment in book-form of a series of essays previously published in the *Cornhill Magazine*. The title forcibly indicates the nature of the subjects discussed, these being generally beyond the pale of exact science, yet possessing in some degree a scientific character. However, with regard to the last three essays, "Gambling," "Coincidences," and "Ghosts," it is difficult to recognize their claim to a position under the title, except in the effort of the author to combat, after an analytical or scientific method, the errors prevailing on those subjects. The essay on "The Herschels and the Star-Depths" sketches the observations of those great astronomers on the "dark portions" of the heavens, and their resulting discoveries of nebulæ. "A Voyage to the Sun," and "A Voyage to the Ringed Planet," in the assumed and fanciful form of a journey to those luminaries, describe their features and the peculiar theories relating to each. "Life in Mars" discusses the reasons for believing that some kind of animal life exists upon that planet, and "A Whewellite Essay on Mars" gives the reasons for doubting that that life resembles such as we see upon our own. Besides several other essays on astronomical subjects is one on "Earthquakes," another on "Coal," and still another on "Flying and Flying-Machines." The clear and vigorous style and varied character of its contents make the book highly interesting. It is to be regretted that it was not published in a cheaper edition.

THE GALVANOMETER AND ITS USES. By C. H. HASKINS. New York: D. Van Nostrand. 76 pp., 12mo

OF suitable size, this book is intended as a pocket manual for students of electricity, as well as a reference-book for experienced electricians. It explains, at the beginning, the laws upon which galvanometric measurements are based, next the galvanometer itself, and lastly the uses of the instrument. It is illustrated throughout. To the end are appended useful tables of the wires and tangents, and of the weights and resistances of iron and copper wires.

MISCELLANY.

Relics of an Ancient Malayan Civilization.—At the November meeting of the California Academy of Sciences, photographs of curious hieroglyphics, cut in wood and found on Easter Island, were received from Mr. Thomas Croft, of Papeeti, Tahiti. In accordance with vague traditions current among the natives, they were supposed to represent the written language of some prehistoric race. The stone idols found on the island exhibit a refined form of art, and other relics found there go to prove that the present population are the degenerate relics of a once powerful nation. In the letter accompanying the hieroglyphics, Mr. Croft stated, from the best information he could obtain, that none except the priests, and a chosen few, could decipher these strange characters. At a recent meeting of the

Academy, another letter from Mr. Croft was read, in which he stated that he had found a native of the island who could read them, and who was going to teach him the language, so that he will shortly be able to translate them. Mr. Croft thinks that he has discovered the relics of a great Malayan empire, which extended its power over that part of the ocean at some former period of the island's history.

Deposits in Steam-Boilers.—Prof. S. Dana Hayes, writing in the *American Chemist* about deposits in boiler-flues, says that they are of two kinds, both of which are capable of corroding the iron rapidly, especially when the boilers are heated and in operation. The most common one consists of soot (nearly pure carbon) saturated with pyroligneous acid, and contains a large proportion of iron if the deposit is an old one, or very little iron if the deposit has been recently formed. The other has a basis of soot and very fine coal-ashes (silicate of alumina) filled with sulphur acids, and containing more or less iron, the quantity depending on the age of the deposit. The pyroligneous deposits are always caused by want of judgment in kindling and managing the fires. The boilers being cold, the fires are generally started with wood; pyroligneous acid then distills over into the tubes, and, collecting with the soot already there, forms the nucleus for the deposit, which soon becomes permanent and more dangerous every time wood is used in the fireplace afterward. The sulphur-acid deposits derive their sulphur from the coal used; but the base, holding the acids, is at first occasioned by cleaning or shaking the grates, soon after adding fresh charges of coal. Fine ashes are thus driven into the flues at the opportune moment for them to become absorbents for the sulphur compounds distilling from the coal, and the corrosion of the iron follows rapidly after the formation of these deposits.

Conditions affecting the Sex of Offspring.—In the *American Naturalist* for January, Dr. John Stockton-Hough has an elaborate article on "The Relationship between Development and the Sexual Condition in Plants." His conclusions are: 1. That in plants, and animals as well, that are actively occupied in vegetative, physiological, pathological, or other efforts which are antagonistic or complementary to the office of reproduction, the proportion of females born during such times is greater than where the plant or animal has reached full developmental maturity and growth, is in good health, and is occupied principally in the process of reproduction. In the latter condition offspring of a higher developmental condition are produced, and the proportion of males is increased. 2. Females are in better condition, more troubled by disease, or other process antagonistic to reproduction, where they conceive with females than with males; and they are poorer, because more exhausted and less healthy, by the production of female offspring, than by male products. 3. It is just possible that the ovules from which females are derived may have a higher initial vitality, though they be less highly developed than those from which males are derived, yet no egg can properly be said to be predestined to be male or female. 4. That female plants, like female animals, are less highly developed than males, and are the result of an inferior developmental reproductive effort on the part of the female parents.

Axial Buds in the Juglans Nigra.—In most plants there is a single bud in the axil of the leaf known as the "axillary bud." In the hickories, walnuts, and some others, there are two or more, one above another, known as supra-axillary buds. When remarking on the sexual characters of the buds of *Juglans nigra*, before the Academy of Natural Sciences of Philadelphia, the specimens I used in illustration made this clear. The abstract in THE POPULAR SCIENCE MONTHLY for April states that the several-sized buds are on the same tree. It should be *at the same node or axis*. Of the three buds, *one above another*, the upper or largest produces a strong branch; the second in order and in size, a female flower; and the lowest, smallest, and least organized, the male catkin. The illustration is very pretty. No one should be satisfied to read about it, but examine the walnut-trees and see for himself.

THOMAS MEEHAN, Philadelphia.

The Potato-Disease.—It is quite certain that the same stock grown on the same land, for several years in succession, deteriorates considerably; and, as the vigor of the plant declines, it becomes more and more susceptible to tae influence of unfavorable weather. It will generally be found, says the *Gardeners' Magazine*, that in a year of disease the sorts regarded by the cultivator with interest as novelties, turn out the best; while those that have been grown on the same spot for several years, suffer most severely. The novelties usually come from a distance, and, irrespective of their intrinsic merits as varieties, they have this peculiar advantage, that they were raised on a different soil, and to some slight extent in a different climate from that they are used to depend on for subsistence.

Generally speaking, says the same magazine, the best seed for strong soils is that raised on peat and bog lands, and seed of excellent quality may be obtained from dry, calcareous soils and newly-broken, sandy pastures. It is very much the custom in England for traders who have to provide largely of seed-potatoes for their customers, to send certain sorts to growers occupying such lands, in order to secure vigorous stocks for cultivation the next year on strong, productive lands. The seed so obtained produces a cleaner crop in a bad season, and a heavier crop in a good season, than seed of the same sorts that has not enjoyed a change of soil for many years. Hence, purchased seed is, as a rule, better than that of the same sort home-grown.

Microscopic Aspects of the Potato-Disease.—Mr. Wenham, writing in the *Microscopical Journal* on the subject of potato-blight, says that a fungus, from the universal presence of the spores in damp localities, and its rapid growth, may appear simultaneously with morbid conditions, and yet not be the primary cause. The grape-vine disease, being cuticular, may be readily traced by the microscope to a fungoid origin, and this origin is further proved by the action of the sulphur-cure, so destructive to fungi in confined localities. This is of no avail in the potato-disease, which, under conditions favorable to its development, is internal and constitutional.

On placing a very thin slice of potato (taken at any time of the year) under the microscope, the cells are seen to be filled with starch-granules, and the walls coated with a layer of active protoplasm of the usual molecular appearance. In the healthy cell, this protoplasm, when seen under the highest powers, with suitable illumination, has a vibratory motion, with feeble currents, in various directions. On approaching the vicinity of the diseased portion, the cell-walls begin to appear of a light-brown color, and wherever the least tinge of this becomes apparent there is no movement, nor can any protoplasm be detected adhering to the wall of the cell, which from that time is a dead member.

Tracing the cell-walls farther, the color deepens, and the septa become thicker, till at last the walls split, giving the now rotten cell a detached appearance; but, from the first indication of disease to the final rotten state, no vital activity can be discovered. In all the phases the starch-granules remain unaltered, completely resisting this peculiar decomposition. The disease is evidently located throughout the tuber, in the substance of the cell-walls. Of its origin Mr. Wenham offers no opinion.

English Honors to an American Astronomer.—The British Royal Astronomical Society has awarded a gold medal to Prof. Simon Newcomb, Astronomer-in-Chief of the United States Observatory at Washington, for his Tables of Neptune and Uranus, and for other valuable astronomical work. The "Investigation of the Orbit of Uranus, with General Tables of its Motion," is the result of fifteen years of labor under the immediate supervision of Prof. Newcomb. Prof. Cayley, of the Astronomical Society, in presenting the medal to Dr. Huggins for transmission to Prof. Newcomb, spoke in very high terms of commendation of the Washington astronomer, and concluded as follows: "Prof. Newcomb's writings exhibit, all of them, a combination, on the one hand, of mathematical skill and power; and, on the other hand, of good, hard work, devoted to the furtherance of astronomical science. The memoir on the lunar theory contains the successful development of a highly-original idea, and cannot but be regarded

as a great step in advance in the method of the variation of the elements and in theoretical dynamics generally. The two sets of planetary tables are works of immense labor, embodying results only attainable by the exercise of such labor under the guidance of profound mathematical skill—and which are needed in the present state of astronomy. I trust that, imperfectly as my task is accomplished, we have done well in the award of our medal."

Nature's Distribution of Trees.—In a note presented to the Philadelphia Academy of Sciences, Mr. Thomas Meehan held it to be an error to suppose that trees are by nature placed in conditions best suited to their growth. Almost all of our swamp-trees grow much better when they are transferred to drier places, provided the land is of fair quality. He referred, among others, to sweet bay, red maple, weeping-willow, and other trees, as within his own repeated observations growing better out of swamps than in them. The reason why they *originate* in swamps is that their seeds can germinate only in damp places, and, of course, in the state of nature, the tree remains where the seed has germinated. Plants, as a general rule, even those known as water-plants, prefer to grow out of water, except those which grow almost entirely beneath the surface. The *Taxodium distichum*, in the Southern swamps, sends up "knees" from various points, often as large as old-fashioned beehives, and several feet above the surface. Not only is the cypress as large when growing in good, rather dry ground, as when growing in swamps, but the tendency to throw up these knees is in a measure lost. With the general facts before us, of the antipathy of swamp-plants to submersion, Mr. Meehan thinks it safe to conclude that these root-excrescences were the result of an effort of the plant to counteract the law which held it, so to speak, in the place of its birth.

Determination of Oxygen dissolved in Water.—At the weekly meeting of the Lyceum of Natural History on Monday, February 16th, as we learn from the *Engineering and Mining Journal*, Prof. Wurtz read a paper on subaërial oxidation. The author is well known to have been for some time engaged in the study of the problems connected with the water-supply of cities. Among these problems, the question of what becomes of the nitrogenous compounds contained in sewage when poured into a running stream, is one of the most important. Oxidation goes on by the action of oxygen dissolved in the water, and Prof. Wurtz has long been studying the means of ascertaining the presence of oxygen in a given water, and of measuring its quantity. To do this he uses a color-test, employing for that purpose pyrogallene, which turns brown under the action of even infinitesimal quantities of oxygen. A sample of water is first made alkaline, and then a drop or two of a concentrated solution of pyrogallene in alcohol is added. If oxygen is present, the result is a brown tint; but, if an aqueous solution of pyrogallene is used, a beautiful pink is sometimes produced. With liquids containing infinitesimal quantities of oxygen, the aqueous solution of the reagent gives a pink color which gradually passes to purple and finally to brown. The depth of the color, therefore, varies with the amount of oxygen, and permits the estimation of the quantity present by the use of graduated standards.

English Fish in Indian Waters.—In December, 1867, Mr. McIvor, Superintendent of the Chinchona Plantations, on the Nilghiri Hills, in Southern India, took out carp, tench, trout, and other fish, with which he has now stocked the rivers, streams, and lakes, of the Nilghiris. The trout have not succeeded well, but the growth and increase of the tench have been marvelous. The first English fish were put in the lake at Utakamund, in August, 1869. In 1871 and 1872 the streams flowing into the lake were well stocked with fish, and for the last few months they have been caught in large numbers by the natives, and sold in the markets. The tench greatly predominate. One interesting fact is that many European fish have been caught below the great Kalhutty water-fall, showing that they have survived after being carried down the highest fall from the Nilghiris, in the descent of the Utakamund Lake and River to the plains. It may, therefore, be expected that the rivers from the foot of the

hills to the sea will eventually be stocked with English tench.

A Clever Shepherd-Dog.—At a field trial of shepherd-dogs held at Bala, in Wales, last October, for a prize of fifty guineas, one of the contestants, a pure-bred Scotch colley, named Sam, performed some marvelous feats which have earned for his portrait a place in the *American Agriculturist*. The duty the dog had to perform was, to drive three sheep, just released from the fold, into a pen with an entrance six feet wide at about five hundred yards' distance. The difficult nature of the performance was increased by the great wildness of the small, wiry mountain-sheep of Wales, which leads them to go in any direction rather than the right one, and each one to scamper off in its own chosen direction. Sam, however, was not to be defeated, and, "surrounding" his three wayward sheep by rapidly-executed flank-movements, had them safely penned in eleven minutes and a half. Sam's next performance was rendered more difficult of accomplishment by sundry unlucky accidents. A flock of geese got mixed up with the sheep, but Sam cleverly extricated his flock. Then two of the sheep jumped over a stone-wall, and the third leaped into the river. Sam persuaded two to come back again, and then hauled the third out of the water by the scruff of the neck and soon had them all in the pen. But, by a mistake of his master, Sam lost too much time, and although his performances were by far the best in other respects, he was adjudged only the third place in the competition.

Eozoon Canadense.—It was the occasion of a great surprise to geological *savants*, when it was announced that the hitherto so-called azoic rocks of the Laurentian formation contained fossil remains. Certain dark-green spherules, not larger than pin-heads, were found speckling the mass, like caraway seeds in a cake. These specks were of hard green-stone, or serpentine. In Northern New York a limestone formation exists, in which these green spherules abound to such an extent as to color or mottle the rock, so that it is called verd-antique marble. These green globules are the same with those in the rocks of the St. Lawrence. They have now for a few years been known by the name *Eozoon Canadense*. Mr. H. J. Carter, in the *Annals and Magazine of Natural History*, as cited in the *American Journal of Science*, seems to have given *Eozoon Canadense* its death-blow. He declares that it is not a *Zoraminifer*, or calcareous rhizopod secretion. It was argued, by those who claimed for it a fossil character, that it was a *Zoraminifer* infiltrated with serpentine. Mr. Carter has made a study of infiltrated specimens of *Nummulites*, *Orbitoides*, and other minute fossils from the Eocene of Western India. These well preserved their foraminiferous structure. But of the *Eozoon Canadense* he says: "In vain do we look for the casts of true foraminiferous chambers at all in the grains of serpentine; they, for the most part, are not sub-globular, but sub-prismatic." He declares himself "at a loss to conceive how the so-called *Eozoon Canadense* can be identified with foraminiferous structure, except by the wildest conjecture."

If, then, this absence of structure thus puts out the claim of this so-called Eozoon, or "dawn of life," may it not be timely to ask what evidence of *structure* there may be in the so-called organism on which the recent attempt has been made to prove the existence of land-plants in the Silurian?

Jasmine flowering early.—For a little time the opening of the winter was severe, after which, until about the close of January, the season was exceptionally mild. It told on the budding of trees generally. At Washington, the *Jasminum nudiflorum*, a Japanese species of jasmine, is cultivated in the open air. This plant burst into bloom about the first of January, some twenty days earlier than is its habit in that latitude.

NOTES.

About 800 miles west of Omaha, says the *Scientific American*, the line of the Union Pacific Railroad crosses Green River, and the approach to the river is for a considerable distance through a cutting of from twenty to forty feet in depth, made in rock. During the construction of the road, some workmen piled together a few pieces of this rock for a fireplace, and soon observed that the stone itself ignited. It has been shown by analysis that the rock, which is a shale,

yields by distillation some thirty-five gallons of oil per ton. The oil so obtained is of excellent quality, and comes over in two or three grades, one suitable for burning and the others for lubrication. The deposits of this rock are supposed to cover an area 150 miles long and 50 broad. They overlie the immense coal-beds of that region, and consist of sandstone impregnated with oil.

THOMPSON'S article "On Cremation" has been twice translated into German, and published once at Cologne and once at Grätz, an Austrian city. The Grätz edition had an introduction by Dr. Kopl, at one time physician to the King of the Belgians. The Communal Council of Vienna has by a large majority adopted a proposal to establish in one of the public cemeteries the necessary apparatus for burning bodies, the use of which will be optional and open to all. The Council of Grätz has passed a resolution to the same effect.

MR. J. L. A. WARREN, author of a valuable treatise on "Silk Culture," is now in Europe, with the intention of visiting the different departments of silk culture and manufacture in France and Italy, and of collecting information for use in his new work on "Silk Culture in Europe and America," which is now in course of preparation.

THE Cowles process for the preservation of clothing from moth and mildew, of which much has lately been said in Congress and in the press, is stated by the *Scientific American* to be based on the preservative action of sulphate of copper on vegetable fibres. By the addition of alum, the preserving qualities of the sulphate are, it is claimed, greatly enhanced; and, when gelatine is also combined, the fibres are said to be not only proof against decay, but also impervious to water. The ingredients are proportioned as follows: Alum, 2 lbs. dissolved in 60 lbs. water; blue-vitriol, 2 lbs. dissolved in 8 lbs. water, to which is added gelatine 1 lb. in 30 lbs. water. A still further improvement is said to made by the addition of acetate of lead, ¼ lb. dissolved in 30 lbs. water. The solutions are all hot and separately mixed, with the exception of the vitriol, which is added cold.

PROF. H. ALLEYNE NICHOLSON, Professor of Natural History and Botany in University College, Toronto, has been appointed to the professorship of Zoology in the Royal College of Science, Dublin. Dr. Nicholson is the author of several well-known works on zoology, the most recent being a "Manual on Paleontology," for the use of students.

FOR the year closing January 1, 1874, the precious metals expressed by Wells, Fargo & Co., produced in North America, made the immense aggregate of $72,258,693. This is in excess of the production of 1872 to the amount of $10,000,000. Nevada alone transmits $35,254,507.

PROF. GRAY mentions, in the *American Journal of Science and Art*, the discovery by Mr. E. J. Hill, on an island in the Kankakee River, in the northeastern part of Illinois, of the *Sphæralcea acerifolia*. This mallow was supposed to exist only in the Rocky-Mountain region and Oregon. Dr. Gray says of this plant, it "is one which probably came so long ago as when Lake Michigan discharged into the Mississippi, the lower part of the Kankakee River being in the direct course of the discharge. The present plants may more probably be regarded, not as chance stragglers, but as lingering remnants indicating an ancient habitat."

PROF. C. V. RILEY, Missouri State Entomologist, has received the high compliment of a gold medal from the Minister of Agriculture and Commerce of France, in recognition of his discoveries in economic entomology, and in particular for services rendered to French grape-culture. It will be remembered that Prof. Riley discovered the American origin of the grape-vine louse, or *Phyllaxera vastatrix*, an insect which threatens the utter destruction of the great vineyards of France. The medal is about an inch and a half in diameter, and bears on its face the figure of "Liberty" in bass-relief, with the words "French Republic." On the reverse is, "To Mr. Riley, of St. Louis, Mo., for services rendered to French viticulture, 1873," encircled by "Ministry of Agriculture and Commerce."

WE note with pleasure the organization of the School and College Association of Natural History, of the State of Illinois. The objects of the Association are: first, to collect, study, and exchange specimens in natural history, and to contribute to a natural history survey of the State; second, to form a State museum; third, to obtain for the schools, with which its members are connected, suitable cabinets of specimens for study and reference; fourth, to encourage and assist the rational study of Nature by the pupils of our schools. An election of officers, on December 31, 1873, resulted in the choice of Dr. Richard Edwards, Normal School, Normal, Ill., for president; S. A. Forbes, curator; and Aaron Gove, secretary. The State Museum at Normal was designated as the centre of exchange and distribution.

A RICH discovery of emery is reported to have been lately made in the northern portion of Pettis County, Missouri.

HERMANN LUDWIG FERDINAND HELMHOLTZ.